CITRUS FRUITS

S P GHOSH

भाकृअनुप
ICAR

INDIAN COUNCIL OF AGRICULTURAL RESEARCH
NEW DELHI

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Citrus Fruits

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Preface

THE Directorate of Information and Publications of Agriculture (DIPA) of the Indian Council of Agricultural Research (ICAR) has planned to bring out a series of publications under its new 'Agri-Popular Series' initiatives. The competent authorities of ICAR have requested the undersigned to write a book on 'Citrus Fruits', under this popular series. Presumably such publications are aimed for addressing the long felt demand of extension workers, developmental agencies, farmers and agri-entrepreneurs. It is indeed a laudable initiative of the ICAR. I am thankful to the Secretary, DARE and Director-General, ICAR, for giving me the opportunity to write the book on citrus.

Citrus fruits as a group are the third most important fruit crops in India. At the global level also citrus production and consumption witnessed a strong growth since mid-1980s, when productions of mandarin orange, sweet orange and acid limes, and lemons have expanded very rapidly. Citrus as fresh fruit and citrus juices as refreshing beverage have large demand globally. Recent estimates show that India has already crossed the 5 million tonnes production mark in 2005.

The R&D programmes in citriculture have received good support and thanks to the efforts of research groups in ICAR institutions and SAUs, very useful technologies have been generated. In this book, proven technologies have largely been compiled for the end-users. The book has 10 broad chapters, with major focus on genetic resources, production and post-production technologies, management of citrus decline, value-addition and marketing of produce, export promotion, R&D and credit support, and on future developmental approach for marking a sound citrus industry in the country.

In this book, published information has been freely used. Some information has been collected from electronic media/website, the sources of which have duly been acknowledged. I would like to record my special thanks to the Director and Scientists of the National Research Centre for Citrus, Nagpur, for providing required technical information and photographs. I hope that the information contained in this publication will benefit the citrus growers, citrus processors, various developmental agencies and other stakeholders involved in the promotion of the Citrus Industry in India.

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15 July 2006
New Delhi

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1

Citrus Industry in India

CITRUS, an important group of fruits, is commercially cultivated in more than 50 countries. Brazil, USA, China, Spain, Mexico, Italy, Argentina, Japan, Australia, Greece, Israel, India and South Africa, are important citrus-growing countries in the world. In sweet group, mandarin orange (loose-jacketed) and sweet orange (tight-jacketed) are mostly used for table purposes. The sweet orange and grapefruit juices are in more demand as refreshing beverage. In acid group, limes and lemons are used for garnishing salads and consumed with other foods. Citrus fruits are rich in carbohydrates, minerals, vitamins, alkaline salts and fibres. The fruit, a type of berry, is called hesperidium. It is highly juicy with almost 80–90% water in its pulp. The peel of some of citrus species are famous for high value peel oil. The composition of commercially important citrus fruits grown in India is shown in Table 1.

Table 1. Composition of commercially important citrus fruits in India

Component	Citrus fruits				
	Mandarin	Sweet orange	Lime	Lemon	Pummelo
Citric acid (%)	0.80	0.55	6.70	5.41	–
Protein (%)	0.90	0.60	1.50	1.00	0.60
Carbohydrate (%)	10.60	8.20	10.90	11.10	10.20
Fat (%)	0.30	0.10	1.00	0.90	0.20
Crude fibre (%)	–	–	1.30	1.70	0.60
Minerals (%)	0.40	0.30	0.70	0.30	0.50
Ca (%)	0.05	0.02	0.09	0.07	0.03
P (%)	0.02	0.02	0.02	0.01	0.036
Fe (mg/100 g)	0.10	0.025	0.30	2.30	0.10
Vitamin C (mg/100 g)	40.00	58.00	63.00	39.00	20.00
Carotene/vitamin A (9 IU/100 g)	350.00	–	26.00	traces	200.00

Source: CSIR (1950), Pruthi (1950).

GLOBAL PRODUCTION AND INDIAN SCENARIO

At global level, production and consumption of citrus fruits witnessed a strong growth since mid-1980s. Production of sweet orange, mandarin (tangerines), and lemons and limes have all expanded rapidly. Due to higher production per caput consumption of citrus fruits has also increased considerably. Improvement of transportation and packaging have resulted in availability of improved processed products in the global market.

According to FAO estimates, during 2002 at the world level citrus fruits were cultivated in 7.33 million ha with a total production of 104.51 million tonnes. Maximum productivity was recorded in USA (35.11 tonnes/ha), followed by Brazil (21.66 tonnes/ha), Spain (19.8 tonnes/ ha) and Italy (17.76 tonnes/ha). During 2004–05, total citrus production in Brazil, Spain and USA decreased by 9%, compared to 2003–04 level. China's production of citrus in 2004–05 is estimated at 12.9 million tonnes, up nearly by 3% from the previous year (*source:* World Horticultural Trade and US Export opportunities, April, 2005 http://www.fas.usda.gov/htp/Hort-circular/2005) and total world export of citrus for major exporters during 2004–05 are estimated at 9.2 million tonnes, down nearly by 4% from 2003–04 level.

Citrus production and consumption in Asia is expected to expand. During 1987–97, Asia experienced maximum annual growth rate of 7.33% and India's growth rate was also very close to it (7.1%). Area expansion has been rapid in China. According to FAO, area-wise China is number one citrus-growing country, covering over 1.46 million ha, followed by Brazil covering 0.93 million ha (2002). Total citrus area in India has been estimated as 0.62 million ha in 2001–02.

According to Indian Horculture Database, total citrus production in India is 4.79 million tonnes, with maximum share of mandarin orange (1.66 million tonnes), followed by acid lime and lemons (1.41 million tonnes) and sweet orange (1.21 million tonnes). In 2005, total production of 5.99 million tonnes with average productivity of 8.4 tonnes/ha has been reported.

The production trend during 1998–2002 clearly established considerable production gains both in sweet orange, and limes and lemons (Table 2).

Table 2. Area and production of major citrus types in India

	Citrus area ('000 ha)		Production ('000 million tonnes)	
	1997–98	2001–02	1997–98	2001–02
Mandarin orange	165.4	198.9	1472.4	1660.1
Sweet orange	67.4	126.4	881.8	1210.4
Acid lime and lemon	129.8	161.3	1101.3	1413.7
Kinnow	–	19.5	–	235.3
Others	–	112.3	–	269.6
Total	487.7	618.5	4310.7	4789.1

Rapid area expansion under sweet orange in preeceding 5 years signifies that the confidence building process in the minds of citrus growers has regained. Sweet orange has earlier been considered as the citrus type where decline problem was most serious. The area expansion trend in sweet orange is clearly noticable both in Andhra Pradesh and Maharastra. In acid lime, which was once under threat due to viral (Tristeza) and bacterial (citrus canker) diseases, also high growth has been reported both in area and production in Gujarat and Bihar. Thus, in spite of the alarm bells of citrus decline, the country has experienced an area expansion by 0.2 million ha and increase in production by 2.7 million tonnes during last 15 years (1988–2002).

The state-wise area, production and productivity of citrus fruits are shown in Table 3 and Fig. 1.

Table 3. Area, production and productivity of citrus in India (2001–02)

State	Area (ha)	Production (tonnes)	Productivity (tonnes/ha)
Maharashtra	168,700	17,30,400	10.3
Andhra Pradesh	144,700	1135,600	7.9
Karnataka	16,800	3,60,200	21.5
Punjab	17,100	2,27,200	13.3
Madhya Pradesh	13,000	2,08,700	16.0
Gujarat	20,200	1,97,800	9.8
Orissa	24,000	134200	5.6
Bihar	16,400	130,000	8.0
Assam	14,800	125,000	8.5
Others	182,900	539200	–
Total	6,18,500	4789,100	7.7

Source: National Horticulture Board, 2003 and NRC for Citrus, Nagpur.

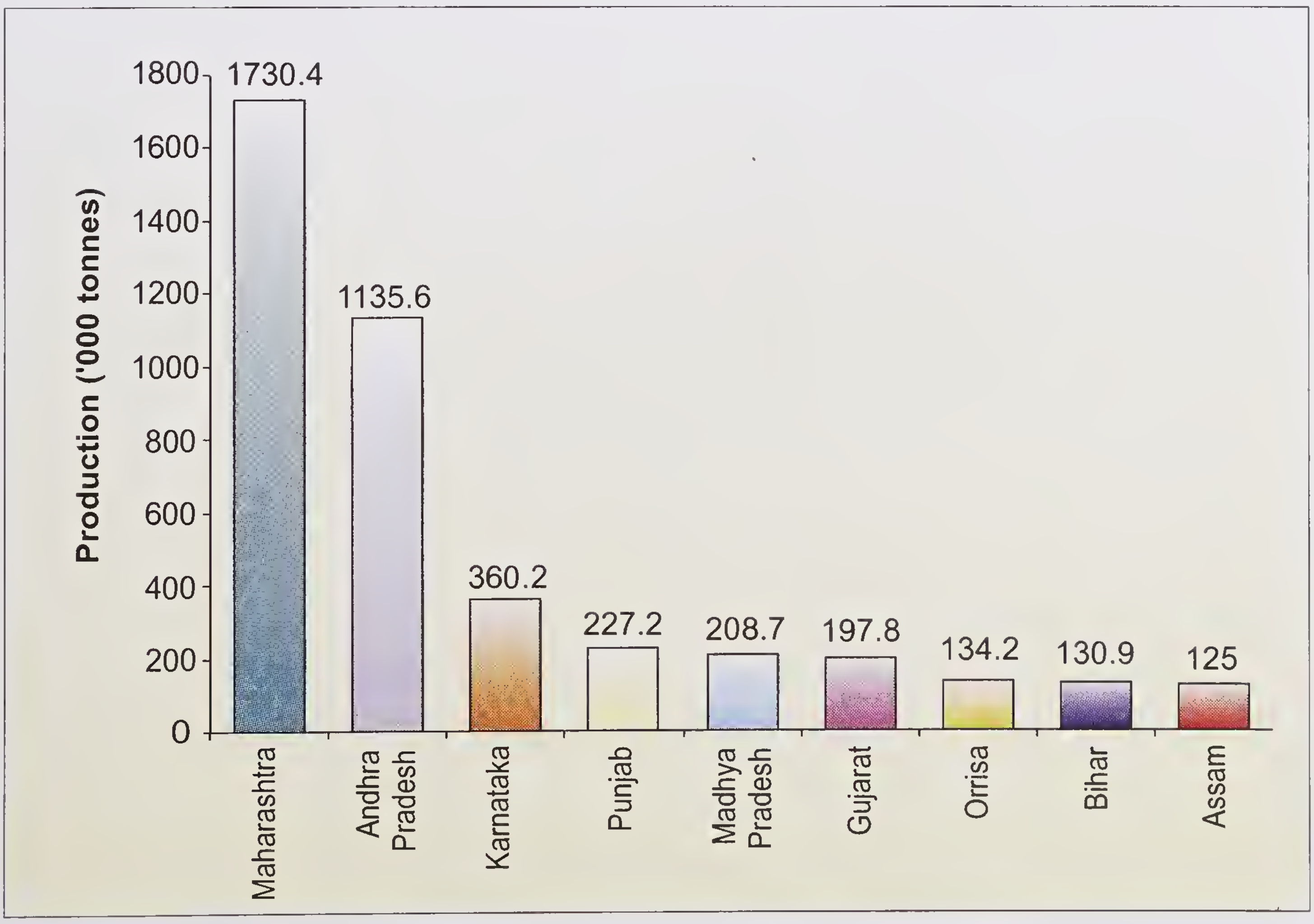


Fig. 1. Leading citrus-producling states (2001–2002).
Source: Indian Horticulture Database 2003; National Horticulture Board, Gurgaon

CITRUS CULTIVATION AND PRODUCTION PROBLEMS IN INDIA

North-Eastern Region

North-Eastern states—Assam, Arunachal Pradesh, Meghalaya, Manipur, Mizoram, Nagaland, Tripura and Sikkim, and Darjeeling hills of West Bengal predominantly grow loose-skinned mandarin orange. Hardly any rootstock is used and entire plantations are seedling origin. 'Khasi' 'Darjeeling' and 'Sikkim' oranges are locally cultivated mandarin varieties.

High rainfall (6–7 months), hill slope cultivation, eroded and heavily leached soil of acid reaction, malnutrition (both major and minor), high infestations of insect-pests are typical in the region. In heavy clay soils of Assam, *Phytophthora* disease is widespread.

North-Western Region

Punjab (Fazilka, Abohar, Faridkat and Bhatinda), Haryana (Sirsa), Rajasthan (Sri Ganganagar) and hills and valley of Himachal Pradesh (Sirmour and Kangra) are mainly covered by 'Kinnow' mandarins budded normally on Rough lemon (Jatti-Khatti) rootstock. Sweet orange (Malta) is largely declined. Irrigated crop in soils of high pH (some places pH 8–9), lime induced micronutrient deficiency, prevalence of *Phytophthora*, greening and other diseases, in some places presence of hard pan near rooting zone, incompatibility of Blood Red Malta on Karnakhatta rootstock are experienced in this region.

Central Region

Most important commercial mandarin orange belt in the country, covering Maharastra (Nagpur, Amravati, Wardha, Yavatmal, Buldana, Akola) and parts of Madhya Pradesh (Chindwara, Mandsaur, and Shajapur) grow 'Nagpur' orange budded universally on Rough lemon rootstocks. In recent years, sweet orange cv. Mosambi is spreading in Marathwada region of Maharashtra and acid lime in Gujarat.

Low rainfall and sub-optimat soil moisture regime, scarcity of irrigation water, high clay content in soil and $CaCo_3$ in sub-soil causes drainage problem and deficiency of N, P and Zn nutrition commonly experienced. Heavy infection of *Phytophthora* and incidence of citrus blackfly induced black sooty mould growth (locally known as 'Kolshi') contributed citrus decline in the region.

Southern Region

Sweet orange (cv. Sathgudi) in Andhra Pradesh and acid lime in Tamil Nadu are grown in low rainfall area, whereas in hilly Coorg region of Karnataka and parts of Kerala, oranges experience high rainfall situations. Sweet orange cv. Sathgudi in Andhra Pradesh is generally budded but in acid lime and mandarins propagation though seed is still prevailing. High soil pH, excess lime and hard pan rich in $CaCo_3$ in certain parts (Kodur) of Andhra Pradesh and Tamil Nadu pose problems resulting to decline. In contrast, in high rainfall, high humidity areas of Karnataka (Coorg) and hills of Kerala, widespread diseases (*Phytophthora*, Greening) and deficiency of micronutrients, particularly Zn, contribute decline of mandarin.

NEW THRUSTS IN INDIAN CITRUS INDUSTRY

Citrus industry in India has faced may challenges due to decline, diseases and management related issues but has come to stay overcoming some of serious problems. Some of special features of India citrus industry and notable changes occurred in more recent times are:

- The traditional mandarin orange cultivation of north-eastern region is seedling origin and no rootstock is being used. The quality of fruits is excellent but the prevailing varieties being highly susceptible, *Phytophthora* disease is very severe in valley region. Use of proper rootstocks and adoption of management practices are crucial for revival of citrus industry in the north-east. The research institutions have already worked out the rejuvenation strategy for mandarin orchards of this region. Under Horticulture Technology Mission (HTM) of Government of India an area expansion of 7,268 ha in citrus has been reported (2004) from north-eastern region of India, of which 4,732 ha is under mandarin orange alone.
- The once famous, Coorg mandarin in Karnataka, is under threat of extinction due to severe infection of greening disease and due to strong competition from other remunerative plantation crops like coffee and small cardamom. Suitable rootstocks have already been identified and programme for large-scale production of disease-free planting material initiated. A local strain of *Trichoderma* sp. has been isolated and found to be effective against *Phytophthora* root rot diseases.
- In the plains of north-western India, sweet orange and mandarins constitute the bulk area under citrus fruits. The mandarin cultivar Kinnow occupies a predominant position in Punjab, Haryana and Rajasthan and has became a highly successful commercial fruit crop. Cultivation practices including drip irrigation and fertilizer applications are followed and budded plants on rough lemon rootstock are highly productive. Export of Kinnow fruits to some of the neighbouring countries has been attempted from this region.
- The Vidharba region of Maharashtra in Central India is the largest concentrated belt of citrus in India, specializing in loose-skinned mandarin variety Nagpur orange. Plants are mainly on rough lemon rootstock and Rangpur lime has been recommended as a drought hardy alternative rootstock. Since the area is tropical, flowering is induced through creation of stress by unique water management practices. Usually two crops, once in November–December and other in March–April are harvested. Advanced production and post-harvest technologies have been developed for Nagpur mandarin and the citrus industry is in good shape and sustainable.

- Sweet orange experienced decline in Punjab and presently sweet orange cv. Mosambi in western Maharashtra and cv. Sathgudi in Andhra Pradesh are cultivated commercially. Virus cleaning through shoot tip grafting (STG), bud wood certification programme for supply of disease-free planting material and cross protection in CTV through isolation and inoculation of milder strains of virus are some of the researchable issues receiving priority attention in sweet orange.
- In acid lime, which is one of the three most important commercial citrus species in India, a few high-yielding varieties (Pramalini, Vikram, Jai Devi, Sai Sarbati) have been released in recent years. For north India lemon cv. Eureka and for north-eastern region a lemon-citron type 'Assam Lemon' are commercially successful. Water management through drip irrigation system and IPM practices are gaining popularity in Indian citriculture.

Indian citrus industry has certain unique features and unlike China and Japan where citrus is grown mainly under subtropical climate, in India both mandarins and sweet orange are grown largely under tropical climatic conditions. For example, famous Nagpur orange (mandarin) is grown in tropical Vidharba region of Maharashtra where summer temperature goes as high as 45–46°C. Both Maharashtra in central India (over 168.7

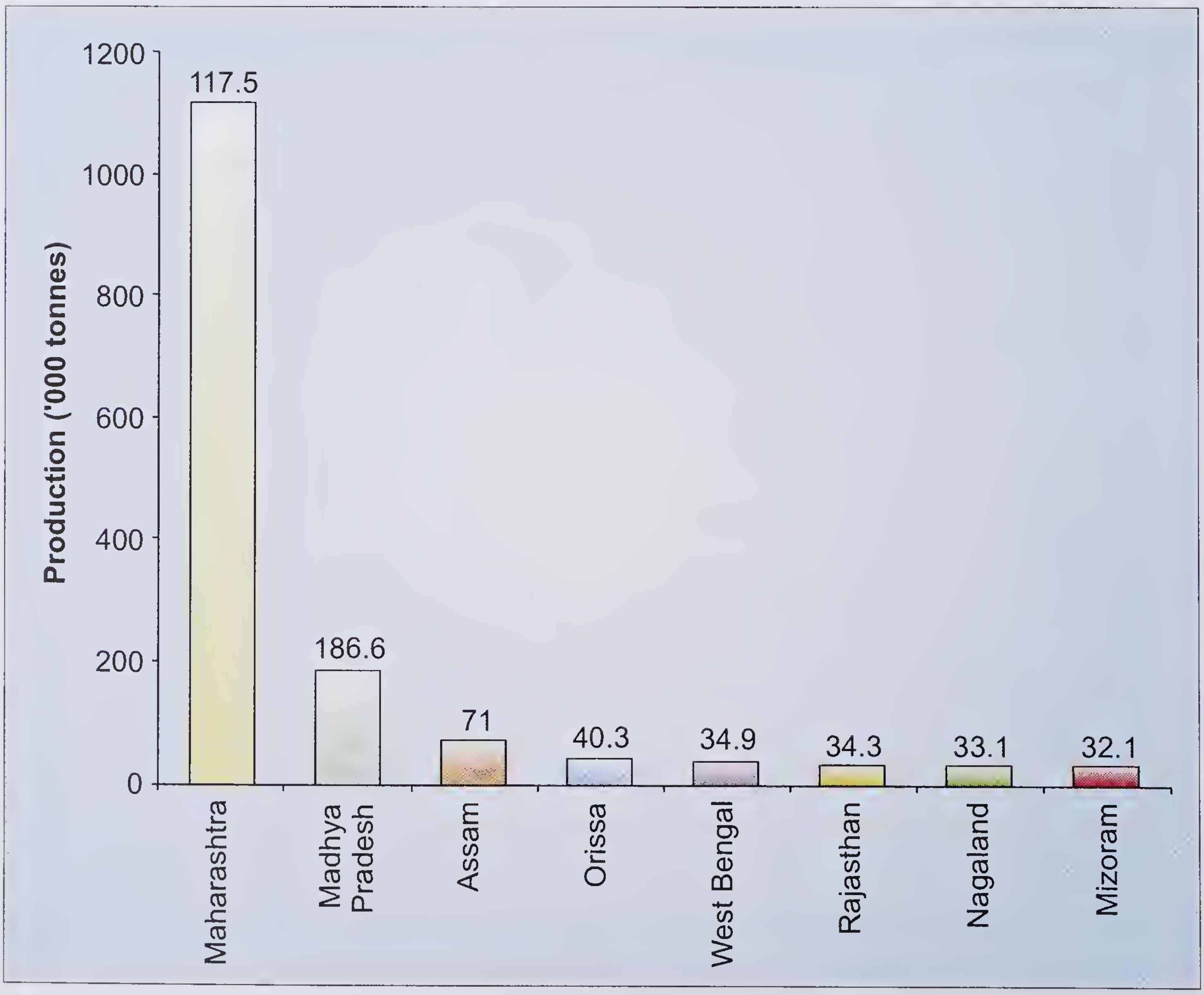


Fig. 2. Leading mandarin orange-producing states, 2001–02.
Source: Indian Horticulture Database 2003, NHB.

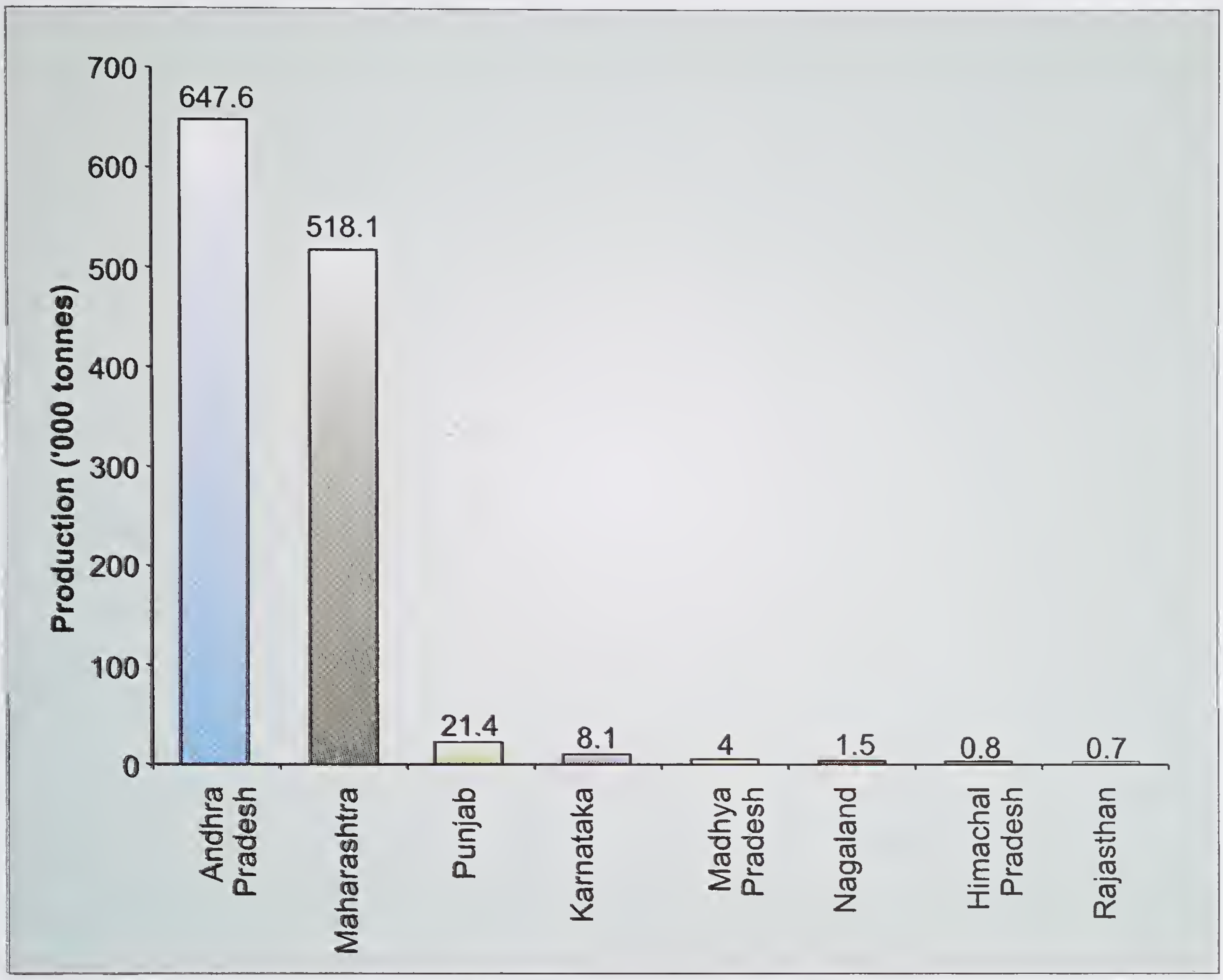


Fig. 3. Leading sweet orange-producing states, 2001–02
Source: Indian Horticulture Database 2003, NHB

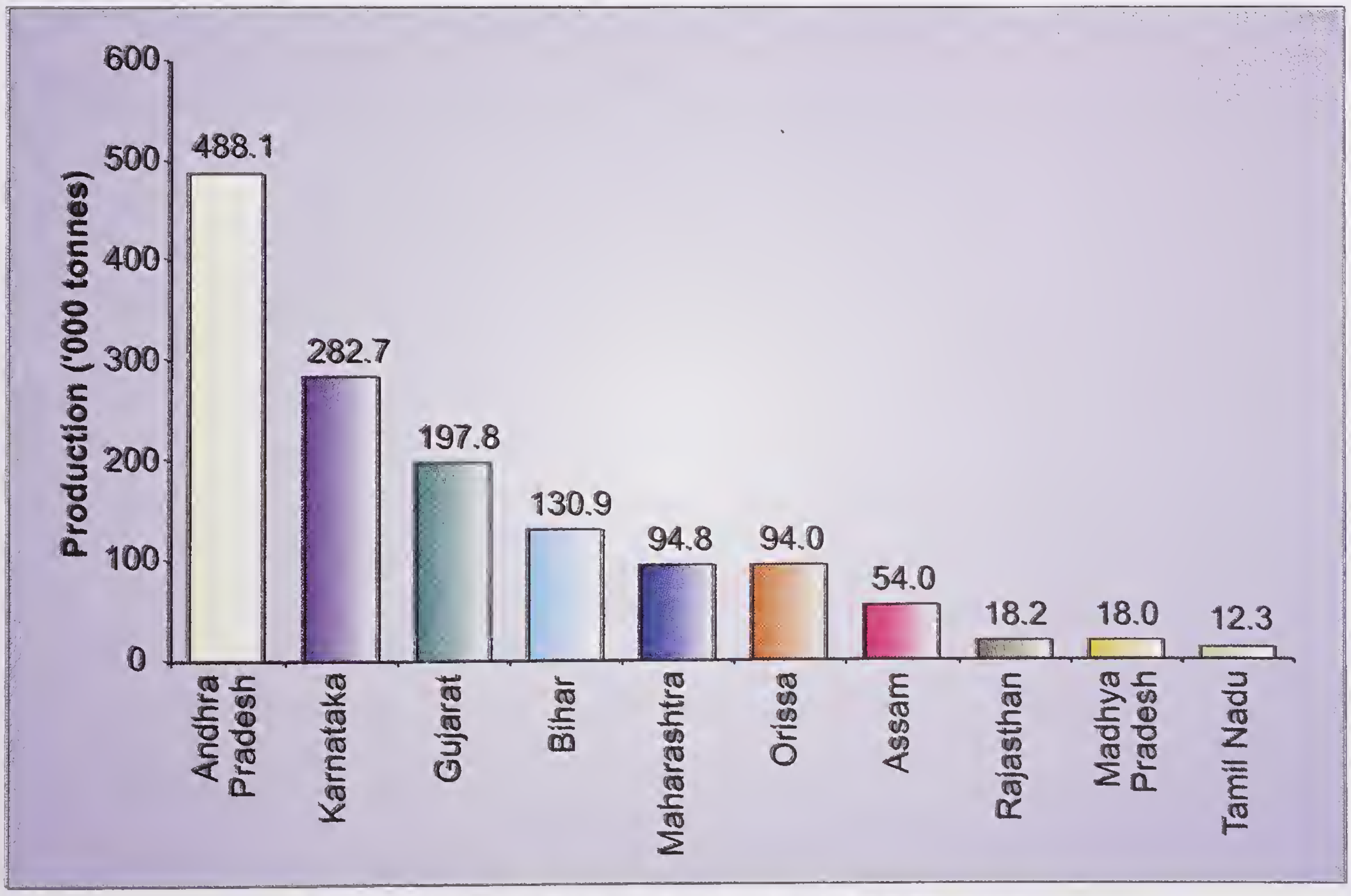


Fig. 4. Leading lime- and lemon-producing states
Source: Indian Horticulture Database 2003, NHB

thousand ha) and Andhra Pradesh is South India (over 144.7 thousand ha) enjoy a distinct tropical climate where there is no well defined winter season with low temperature regime. The Kinnow mandarin, however, is showing good promise and is commercially successful in Punjab, Haryana and Rajasthan falling under subtropical climate with distinct winter season. Similarly, the traditional mandarin growing areas of north-eastern hills and Coorg area of Karnataka state experience subtropical climate with high rainfall and low temperature during winter months.

In India, there are 26 states involved in citrus production. But 9 states cover more than 70% of area and 89% of the total production. However, data show that there exists very high degree of disparity in area and production vis-à-vis productivity. For example, Maharashtra ranks first in area and total production but productivity-wise it ranks fourth with 10.3 tonnes/ha after Karnataka (21.5 tonnes/ha), Madhya Pradesh (16 tonnes/ha) and Punjab (13.3 tonnes/ha). In spite of poor yield in Maharashtra, there is almost four-fold increase in area under citrus during 1968–69 to 1991–92 period. Market analysis revealed very high rise of price in citrus in 4 years period of 1989–93, when the percentage increase was 46.8% in mandarin and 32.3% in sweet orange. The high market price and steady increase in demand in domestic market kept citrus cultivation highly remunerative. Doubling of yield of citrus in Maharashtra from 5.7 tonnes/ha in 1991–92 to 10.3 tonnes/ha in 2001–02 has become possible with available production technologies generated by the research system.

The Leading states in terms of production of mandarin orange, sweet orange and limes and lemons are shown in Figs 2–4 respectively.

2

Genetic Resources of Citrus

INDIA is a major centre of diversity of citrus fruits with main regions of diversity being North-Eastern India, North-Western Region, the foothills of the Himalayas and the Western Ghats. Systematic collection and characterization only started in the 1950's and collections were conserved at different locations. The genepool is largely conserved in field genebanks as working collections which represent phylogenetic relations of major citrus groups. Indigenous citrus species were described and have been evaluated for their use as rootstocks and as sources of resistance in breeding programmes.

INDIGENOUS GERMPLASM

It is believed that most of the species under the genus Citrus are native to tropical and subtropical regions of southeast Asia, particularly India, China, and the region between these two countries. The north-eastern region of India is considered as one of the natural homes of citrus, at least for a few species. Certain non-edible species like *Citrus indica, C. ichangensis, C. macroptera, C. latipes* grow in wild and semi-wild states in north-eastern region. Bhattacharya and Dutta (1956) considered them as indigenous to the area. Also, different strains of citron (*C. medica*), sour pummelo (*C. megaloxycarpa*), rough lemon (*C. jambhiri*) and sour orange (*C. aurantium*) have been found to grow widely in semi-wild conditions in different north-eastern states (Verma and Ghosh 1979). It is possible that since very early years there might have been spread of different citrus species in contiguous regions of their natural home. There are also possibilities of free exchanges of citrus germplasm from one country to other, particularly between China and India.

Bhattacharya and Dutta (1956) described 17 Citrus species, their 52 varieties and seven probable nature hybrids from the north-eastern region. The varieties described and classified by them are:

- *Citrus medica* L. (Bira Jora, Soh Manong, Mitha Jora)
- *C. limon* Burm. (Naya Changney, Assam lemon, Pati, Lebu, Jora Tenga, Gotha Pati Lebu, Mata Jamuri, Elachi Lebu, Soh Synteng, Pani Jamir)
- *C. jambhiri* Lush. (Soh Myndong, Kata Jamir, Soh Jhalia, Sindhuri Nemu Tenga, Mitha Tulia)
- *C. karna* Ref. (Soh Sarkar)
- *C. aurantifolia* Swing. (Abhayapuri lime, Karimganj lime)
- *C. limetta* Risso. (Mitha Kaghzi)
- *C. reticulata* Blanco. (Soh Niamtra, Soh Umkdait, Naga Santra, Soh

Siem, Kapura Tenga, Narangi).

- C. *nobilis* Lour. (Jeneru Tenga)
- C. *indica* Tanaka. (Indian wild orange, Memang Narang)
- C. *sinensis* L. Osbeck (sweet orange, Soh Nairiang, Soh Bitara)
- C. *aurantium* Linn. (Karun jamir, Gobdh Huntra)
- C. *maxima* Merr. (Dowadi, Nowgong, Jorhat, Khanapara, Kamrup, Khasi, Burni, Zemabawk, Aijal)
- C. *grandis* Lush. (Bor Tenga, Hukma Tenga, Holong Tenga, Jair Tenga)
- C. *ichangensis* Swing (Ketsa Seupfu)
- C. *macroptera* Montr. (Satkara, Tith kara)
- C. *latipes* Tanaka. (Soh Shyrkhoit)
- C. *assamensis* Dutta & Bhatta.

The natural hybrids described by Bhattacharya and Dutta (1956) are: (i) Soh-Khyllah No. 1, (ii) Soh-Khyllah No. 2, (iii) Soh-Khyllah No. 3, (iv) Hashkhuli, (v) Sarbati, (vi) Nicholsroy, (vii) Dewa tenga.

Verma and Ghosh (1979) described some economically desirable characteristics of local citrus germplasm collected from different north-eastern hill states of Maghalaya, Manipur, Nagaland, Sikkim and Arunachal Pradesh. The salient features of some of the important types collected are:

- ***Citrus indica* (*Indian wild orange*):** Earlier trees of this species were reported to occur in certain parts of Assam and Nagaland. The species was found to grow wild in Garo Hills (Sesatgiri) of Meghalaya, where the local vernacular name is 'Memang Narang'. The bushy plants were found to grow near marshy areas in forests. The fruits are small-sized, inedible with slimy juice of acidic taste. The seeds are very bold, while the aroma is unpleasant.
- ***Citrus macroptera:*** Fruits were collected from Meghalaya (locally called Satkara) and Manipur (locally known as Garebo). They were found to grow in the Mizoram and Jampui hills area of Tripura. The fruits, which are highly juicy and acidic are used by the local tribals for home consumption and for medicinal purpose.
- ***Citrus latipes:*** Trees of this species are quite vigorous even at high altitudes (1,500–1,900 m above msl) in Meghalaya, where it is known by the local Khasi tribals as 'Soh Shyrkhoit'. Fruits which have no market value are moderately juicy and acidic in taste.
- ***Citrus assamensis:*** Locally known as Adajamir, the fruits and leaves are distinct with a ginger like aroma. The fruits are consumed by local people and are acidic and highly juicy.
- ***Citrus limettoides:*** An interesting type (Soh Jew) where fruit is sour in taste could be collected from Jainta hills of Meghalaya. The tree and fruit characteristics are very similar to those of sweet lime and the type appears to be a sour mutant of C. *limettoides.*
- ***Citrus jambhiri:*** Out of 15 types of rough lemon collected, seven types with distinct morpho-anatomical characters, were considered as seven distinct strains (Ghosh *et al.,* 1982). Fruits of some of the

strains were highly juicy and local tribes use them for table purposes like lemons and limes. Even in high altitudes (about 1,500 m) rough lemons are found to grow well.

- ***Citrus medica* (Citron and lemon—citron group):** Citrons are widely distributed in the entire region and they were found to grow wild covering considerable areas in the Garo Hills of Maghalaya and Siang district of Arunachal Pradesh. There are certain scented types, while some of the other prevailing types, with profuse bearing habits, thin rind and good juice contents, may have good commercial value for table use. Cirtons with very large fruits and thick, hard rinds are also common.
- ***Citrus auratium* (Sour orange):** A few types of sour orange may be collected from the region. A vigorously growing, round fruited type, with distinct deep orange red skin and orange coloured pulp has been found to grow in a semi-wild condition in Mokokchung district of Nagaland.
- ***Citrus grandis* (Pummelo):** A good amount of variability exists in pummelo cultivars grown mostly at the homeyards of Assam and other states of the region. Earlier, nine different forms or types were described by Bhattacharya and Dutta (1956). Seven more types were collected, of which three types had desirable characteristics like thin rind, high juiciness and high TSS content juice. These may prove to be of good economic value.
- ***Citrus sinensis* (Sweet orange):** Certain interesting local types, namely Soh-Nairiang and Soh-bitara of Meghalaya and Tasi of Arunachal Pradesh with aciduously sweet fruits are of limited commercial value. All three types exhibited vigorous growth even at high altitudes (1,500 m) and are commonly found to grow as novelties in many houses in the Khasi and Jaintia hills of Meghalaya and in the Siang district of Arunachal Pradesh.

The Soh-Nairiang plants are vigorous and upright in growth habit and are usually very heavy bearing. The pulp is orange coloured and fruit is tight skinned. The Soh-bitara, which is very common in the Jaintia Hills of Meghalaya, has yellowish coloured fruit pulp and the fruits fetch good market prices. The Tasi of Arunachal Pradesh grows in an almost semi-wild state in the Along belt of Siang district of Arunachal Pradesh, where the trees are vigorous with deep green glossy leaves. The fruits are very juicy and taste aciduously sweet.

- ***Citrus reticulata* (Mandarin orange):** The mandarin orange, which is the most important commercial citrus fruit of the region, exhibits some morphological variations. These are mainly in the fruit characteristics and are mostly attributed to locational differences.

In south India, the indigenous types include Gajanimma (*C. pennivesiculata* Tan), Kichli (*C. maderaspatana* Hort. Ex. Tan) and some wild mandarin types, viz. Kodakithuli, Billikichili, Nakoor lemon, Mole Puli (Sour orange type). In the foothills of western Himalaya, the hill lemon Galgal (*C. rugulosa* Hort. Ex. Tan) are common. Citron, Citron-lemon, Karna Khatta, Rough lemon, Rangpur lime, acid lime, hybrid pummelo and different types of mandarins are found all over the country.

GERMPLASM CONSERVATION

Ex-situ conservation of germplasm of citrus has been addressed but very little has been done for *in-situ* conservation.

In-situ conservation

Many of the wild citrus types are reported to occur in north-eastern region, Western Ghats and on the Chotanagpur Plateau. Fruits of many wild types are small but may be potential gene sources for resistance. Thus, attempts to preserve the native habitat of *C. indica,* a progenitor of mandarin, was initiated in 1978 by National Bureau of Plant Genetic Resources, New Delhi. A gene sanctuary for *C. indica* was established in the Tugra Range in Garo hills of Meghalaya. The core area of this site is 10,266 ha with a buffer zone demarcated. This is the first gene sanctuary for the conservation of endangered citrus spices and is maintained as reserve forest by the Forest Department of Meghalaya.

Field genebank

Citrus germplasm resources are maintained under different agroclimatic conditions of the country. A good collection, both indigenous and exotic are maintained at NRC for Citrus, Nagpur; Central Horticultural Experiment Station, Chethlli, Karnataka; Indian Institute of Horticultural Research, Bangalore; Regional Fruit Research Station, Abohar, Punjab; Horticultural Experiment Station, Bhatinda, Punjab; Division of Fruits and Horticultural Technology, IARI, New Delhi; Department of Horticulture, Rahuri, Maharashtra; Citrus Improvement Project, Tirupathi, Andhra Pradesh; Citrus Experiment Station, Katol, Maharashtra; Horticultural Experiment station, Periyakulam, Tamil Nadu; Citrus Experiment Station, Tinsukia, Assam and others. The details of citrus germplasm maintained at different field genebanks are shown in Table 4.

USEFUL CHARACTERISTICS OF LOCAL GERMPLASM

Disease and Stress Tolerance

Strains of rough lemon and Rangpur lime screened against *Phytophthora* exhibited varying degrees of resistance. In rough lemon one strain collected from south India (Coorg) showed a high degree of survival (94%) in inoculated samples.

In acid lime, one seedless type and variety known as 'Nepali Oblong' were found to be resistant to canker. Another acid lime selection (Selection 49) developed at Rahuri, Maharashtra, showed only 30% disease incidence against an average infection of 85% for other varieties. Screening for

Table 4. Total pool of citrus germplasms maintained at genebanks of different citrus belts in India

Site/location	Number of accessions
North-west India	
RFRS (PAU) Abohar, Punjab	132
PAU, Ludhiana	76
HRRS (YSPUHF), Dhaulkuan, Sirmour, Himachal Pradesh	11
NEH Region	
Citrus Research Station, AAU, Tinsukhia, Assam	36
ICAR, RC, Umiam, Meghalaya	92
Central India	
NRC for Citrus, Nagpur, Maharashtra	537
PDKV, Akola, Maharashtra	18
RFRS (Dr. PDKV), Katol, Maharashtra	33
HRS (Maharashtra Agric. Univ.) Parbhni, Maharashtra	68
Mahatma Phule Krishi Vidyapeeth, Rahurdi, Maharashtra	66
FRS (Mahatma Phule Krishi Vidyapeeth), Srirampur, Rahuri	34
South India	
RRS (IIHR) Chethali, Karnataka	126
IIHR, Hessarghatta, Bangalore, Karnataka	76
HRS (TNAU), Periyakulam, Tamil Nadu	20
S.V. College of Agriculture, Tirupati	115
HRS (TNAU), Yercad, Tamil Nadu	41

Source: Based on reports of AICRP (Tropical Fruits) compiled by I.P. Singh and Shyam Singh (2003). Technical Bull. 7, NRC for Citrus, Nagpur.

incidence of citrus greening disease (Kapur *et al.,* 1977), covering 15 citrus species and 24 cultivars showed that Gajanimma (*C. pennivesiculata* Tan) and Karna Khatta (*C. karna*) were free from disease. Rangpur lime also exhibited greater salt tolerance, where accumulation of sodium, even up to 1%, did not lead to visible injury to the plants. The salt tolerance is mainly attributed to differential uptake and accumulation of salts with the tolerant rootstock having the capacity to exclude chloride ions.

Rootstock varieties have been evaluated for their tolerance to drought. In studies conducted at Tirupathi (South India), Rangpur lime was found to be highly tolerant to drought, maintaining water balance even at low soil moisture levels. In other states, Rangpur lime has also been found to be more drought hardy when compared to standard rootstocks like rough lemon.

Against citrus nematodes, rough lemon strains Poona, and 8,782 were moderately resistant.

Processing Quality and Value

Eight varieties of lime, Mosambi (sweet orange), Nagpur santara, grapefruit, sweet lime and Galgal (*C. limonia*) were evaluated for physicochemical characters of their juice. Ascorbic acid reduction was greater in Mosambi orange, Nagpur santara and sweet lime, while it was less in acidic fruits like lime and Galgal.

Nagpur santara, orange and grapefruit exhibited colour deterioration. Tight skinned sweet orane varities like Malta, Sathgudi and Mosambi gave bitter free juices, while loose-skinned mandarin varieties like Nagpur and Coorg developed a bitter taste over time. Velencia orange and Coorg mandarin juice are better suited for juice concentrates. Fresh orange peel yielded about 0.54% oil. It can be extracted either by cold press method or by distillation, of which the former is preferred. Coorg mandarin and Nagpur oranges are better suited for oil extraction. Peel oil is also extracted from limes, Kinnow mandarins, Karna Khatta and Malta orange.

Citrus peels and residues contain 2.5–5.5% of pectin. Citrus peel after extracting peel oil and the pulp and residue after extracting juice are used for pectin extraction. Pectin is used as a thickening agent in preparation of ketchups, sauces, etc. as an emulsifier in preparation of ice cream and for increased glaze of candied fruits. Different workers have evaluated varieties for pectin content. Citron has high medicinal value and is used for several ailments.

MAJOR CITRUS SPECIES OF HORTICULTURAL IMPORTANCE

Mandarin orange (*Citrus reticulata*)

A highly polyembryonic species of Chinese origin, having medium-sized upright trees, leaves lanceolate in shape with narrowly-winged petiole. Fruits medium-sized, globose, sweet in taste, segments easily separable, core open at maturity, loose-skinned, orange in colour, rind thin, rind and segments easily separable, usually 10–14 segments in each fruits; seed pointed with light green cotyledons. The important cultivars are Nagpur, Coorg, Khasi, Sikkim, Darjeeling mandarin of India. Ponkan of China, Satsuma of Japan, Kinnow are other important varieties.

Sweet Orange (*C. sinensis*)

A highly polyembryonic species of Chinese origin. Trees medium-large with blunt-pointed leaf apex and narrowly-winged petiole. Fruits subglobose to oval in shape, orange or reddish in colour, with smooth peel; pulp juicy and sweet and flesh colour is usually orange. Seeds are with whitish cotyledons. The species is of great economic importance for its excellent quality as well as for its processing value. Quite a large number of cultivars, viz. Mosambi, Malta Blood Red, Sathgudi of India, Valencia, Pineapple, Washington Navel (having a rudimentary secondary fruit embedded in the fruit apex) of the USA, Shamouti of Israel, Succari of Egypt, Dobla Fina of Spain, etc. are some of the commercially important cultivars.

Pummelo (*C. grandis, C. maxima*)

A monoembryonic species with large-sized fruits, considered to be indigenous to Malaya and Polynesia. Spreading, round-topped, almost thornless tree. Leaves large with broadly-winged petiole. Lower surface of leaf is pubescent, particularly the main vein.

Lemon (*C. limon*)

A weakly poyembryonic species with medium-sized spreading trees. The new flushes are pigmented. Leaves not dark green and leaf margins are subserrated. Petioles medium-sized and narrowly winged. Flower buds pigmented and the pistil is densely dotted with oil glands. Fruits oval to elliptic with pointed nipple. Fruit surface smooth, light yellow and core solid; juice abundant and acidic. Seed cotyledons are white. The species is of great commercial importance and the cultivars like Eureka and Lisbon (USA), Femminellow and Monachello (Italy), Bernia (Spain) are important. The so-called bush lemon types (lemon-citron) like Kagzi Kalan, Italian Round, Assam lemon, etc. are of good demand.

Acid lime (*C. aurantifolia*)

A highly poyembryonic, distinctive species of great commercial importance. Tree is small, bushy with small but sharp spines. Leaves small with narrowly-winged petioles. Flowers and fruits small. Fruits round to oval, maturing irregularly throughout the year, greenish yellow in colour and thin skinned. Core solid at maturity, flesh greenish in colour and juice highly acidic. Seeds small, smooth and cotyledons whitish. The Kagzi lime is the most important commercial cultivar of India. The cultivar is highly susceptible to tristeza virus, and bacterial canker disease.

Sweet lime (*C. limettoides*)

A highly poyembryonic species of Indian origin. Trees medium-large and spreading in growth habit. The leaves medium-sized, petiole wing margined, leaf lamina light green and characteristically cupped (somewhat rolled). Flowers and fruits larger than acid lime and globose to ellipsoid in shape. Fruit surface smooth, greenish yellow with thin rind. Flesh pale yellow to straw colour, core semi-hollow at maturity, flavour insipid, juice sweet (flat) with little bitter aftertaste. Seeds medium in size with white cotyledons. There is no named cultivar, the 'Mitha-nimbu' or 'Sharbati' of India belongs to this species. It is commercially grown in certain countries like Egypt and has been employed as rootstock.

Rough lemon (*C. jambhiri*)

A highly poyembryonic species of Indian origin (Dutta, 1958). Tree medium to large and spreading in growth habit. Leaves are light green and serrations of leaf margin are not sharp. Fruits differ distinctly in shape and colour from roundish to subglobose shape with cavity or depression surrounding the apical papilla or nipple. Fruit skin usually rough and lemon-brown in colour. Flesh colour yellow, core open at maturity, better suited to light soils. It is fairly tolerant to many citrus virus diseases, including tristeza.

Rangpur lime (*C. limonia*)

A vigorous, hardy rootstock with good adaptability to wide range of soil, particularly for heavy soil. It is tolerant to tristeza and also to salt. Rangpur lime is drought hardy and the quality of fruit of mandarins on Rangpur lime is fairly good. It has been recommended as a suitable rootstock for mandarins.

In citrus, phenomenon of polyembryony is very common. Mandarins, acid lime, grapefruit are highly polyembryonic, whereas pummelo, citron and lemons are monoembryonic. Citrus germplasm has been extensively studied and utilized in breeding programme. Trifoliate orange and sour orange have been utilized in breeding programme Very useful work has been done in citrus breeding, resulting in development of improved scion varieties as well as rootstocks (Reuther *et al.*, 1967). Trifoliate orange and sour orange exhibits high degree of resistance against *Phytophthora* root rot. Rangpur lime has been found to be drought hardy and some what tolerant to salt and therefore being used as a rootstock. Citrange (trifoliate orange × sweet orange) are considered as good rootstocks for some scion varieties. A citrus hybrid (King mandarin × Willowleaf mandarin) known as "Kinnow" has been a commercial success both in India and Pakistan. Some of the commercially important citrus

Table 5. Commercially important citrus fruits

Species	Cultivars
Mandarin	Nagpur mandarin, Khasi mandarin, Darjeeling mandarin, Kinnow, Satsuma, Ponkan
Sweet orange	Mosambi, Sathgudi, Blood Red Malta, Hamlin, Pineapple, Valencia, Jaffa, Washington Navel and Shamouti
Acid lime	Kagzi lime, Vikram, Pramalini, PKM-1, Tahiti and Mexican lime
Lemon	Lisbon, Villefranca, Assam lemon, Gandhraj, Seville lemon, Nepali lemon, Italian lemon, Eureka lemon
Grapefruit	Duncan, Marsh Seedless, Ruby, Foster
Pummelo	Shantian You, Wenden You, Red Fleshed, White Fleshed, Krishnanagar

Table 6. Characteristics of selected rootstocks of citrus

Rootstock	Horticultural traits			Reaction to diseases				Others		
	Yield	Quality	Plant vigour	Root rot	Citrus nematode	Tristeza	Exocortis	Salt T	Drought T	Root system
Rangpur lime	G	M	G	MT	S	R	S	R	R	D
Rough lemon	G	L	G	S	S	R	R	T	T	D
Cleopatra mandarin	M	M	M	T	S	R	R	MT	D	M
Trifoliate orange	L	M	L	R	R	R	H	HS	HS	Sh
Troyer Citrange	M	G	M	MT	T	MT	S	HS	HS	Sh

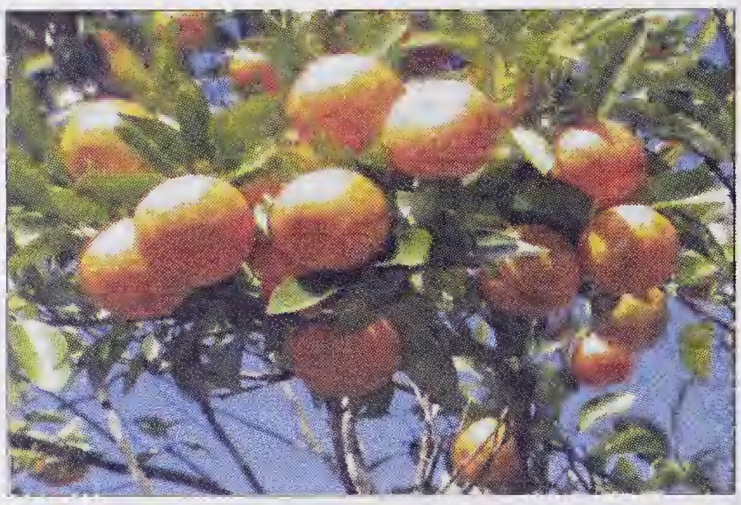
G: Good, M: moderate, L: poor or low, R: resistant, T: tolerant, MT: moderately tolerant, S: susceptible, HS: highly susceptible, D: deep, M: medium, Sh: shallow.

Table 7. Commercial varieties of citrus in India and their distribution

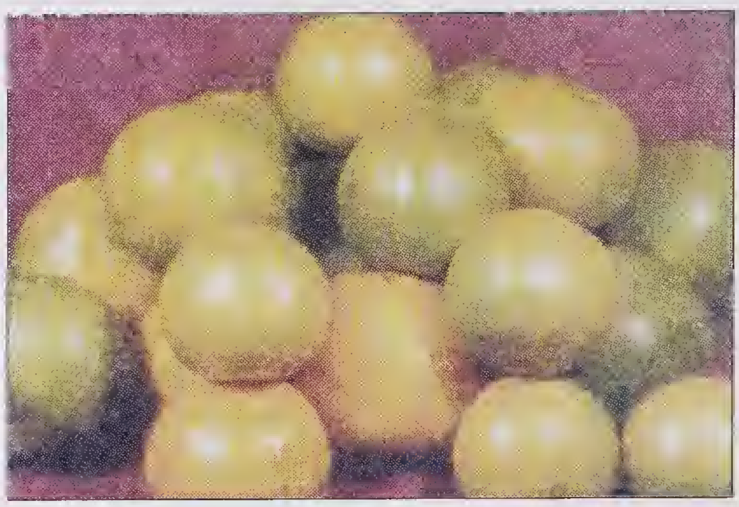
Citrus group	Cultivars	Distribution (state/region)
Mandarin orange	Nagpur orange	Maharashtra, Madhya Pradesh
	Khasi orange	North-eastern states
	Darjeeling orange	Darjeeling district of West Bengal
	Sikkim orange	Sikkim
	Coorg orange	Coorg region of Karnataka
	Kinnow orange	Punjab, Rajasthan, Haryana
Sweet orange	Mosambi	Maharashtra
	Sathgudi	Andhra Pradesh
	Jaffa, Valencia,	Punjab
	Hamlin, Malta	Rajasthan
Acid lime	Kagzi lime	Andhra Pradesh, Tamil Nadu Karnataka, Maharashtra
Lemon	Hill lemon, Galgal	Uttar Pradesh, Himachal Pradesh,
	Assam Lemon	Assam and North-eastern states
	Eureka, Baramasia,	Karnataka,
	Lisbon Lemon	Uttar Pradesh

varieties are given in Table 5. Similarly, characteristics of different citrus rootstocks are given in Table 6. The commercial varieties of citrus cultivated in different regions of the country are shown in Table 7.

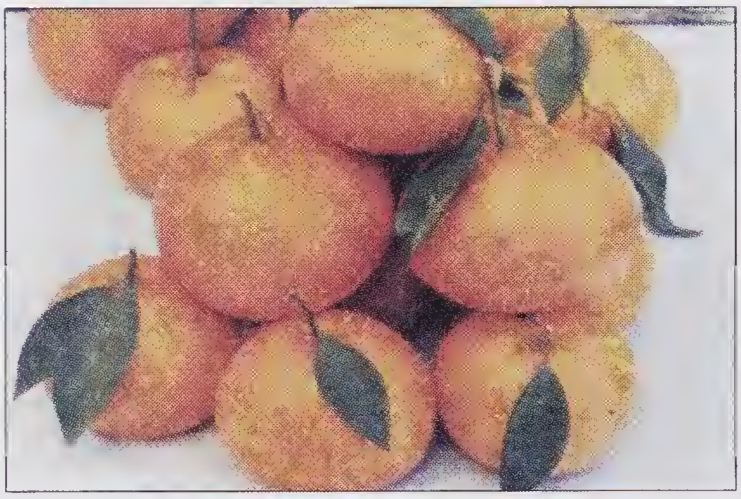
Important varieties of citrus fruits grown in India



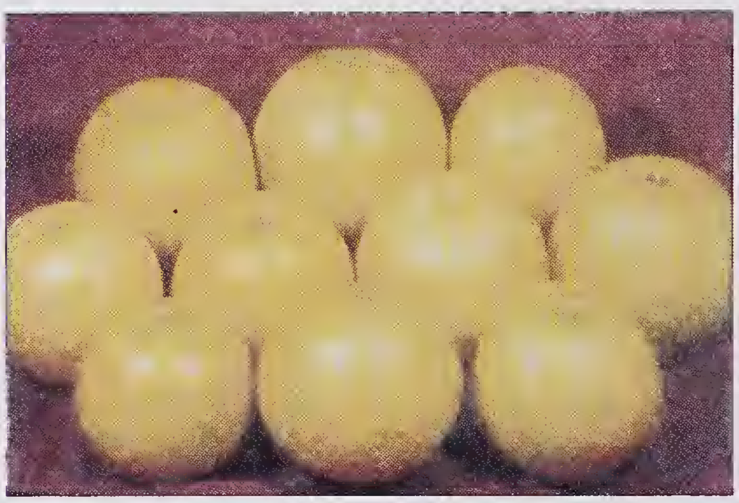
'Khasi' Mandarin Fruits



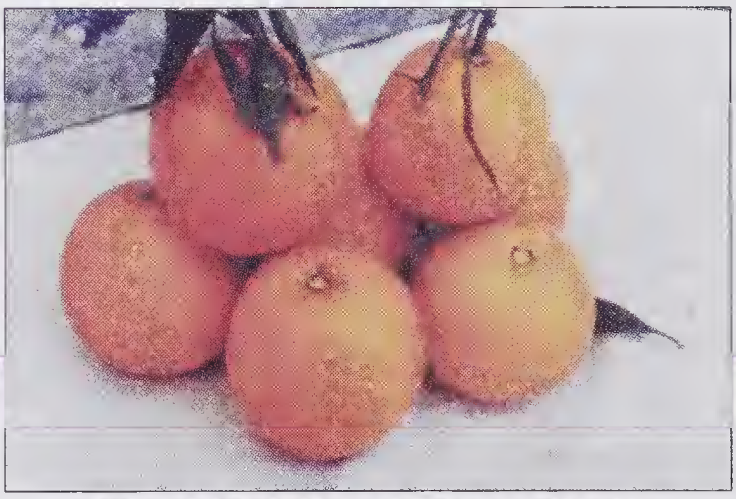
'Nagpur' Mandarin Fruits



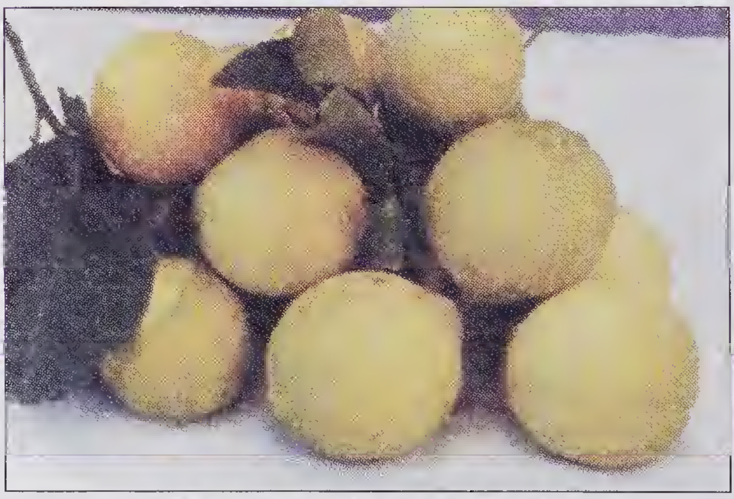
'Kinnow' Mandarin Fruits



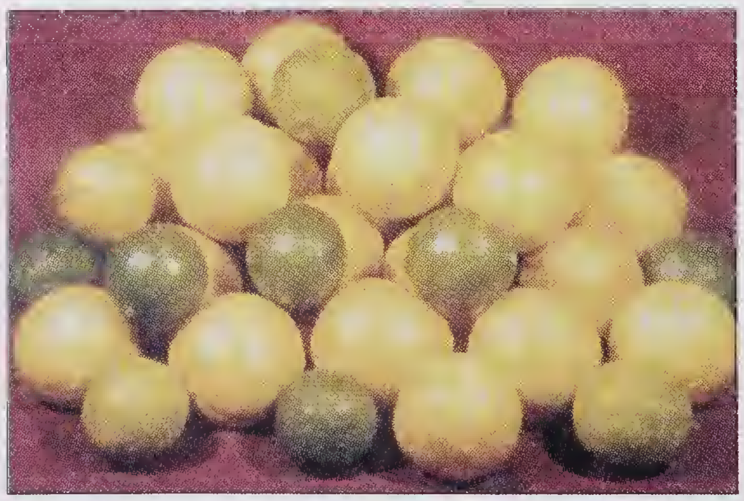
'Sathgudi' Sweet Orange Fruits



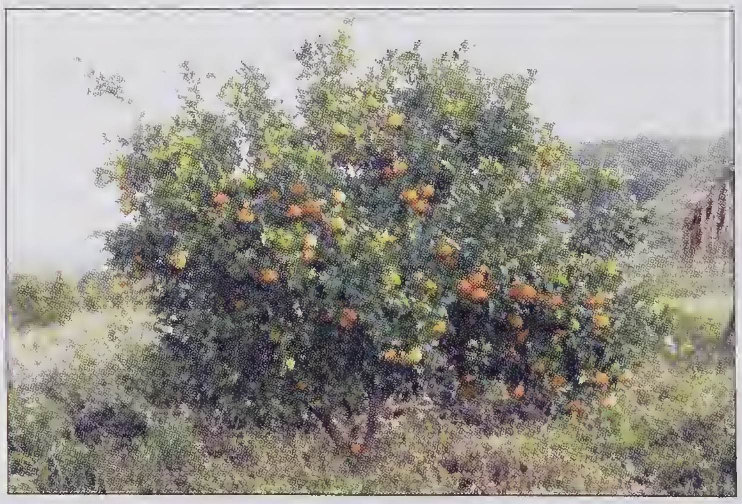
'Blood Red' Sweet Orange Fruits



'Baramasi' Lemon Fruits



'Kagzi' Acid Lime Fruits

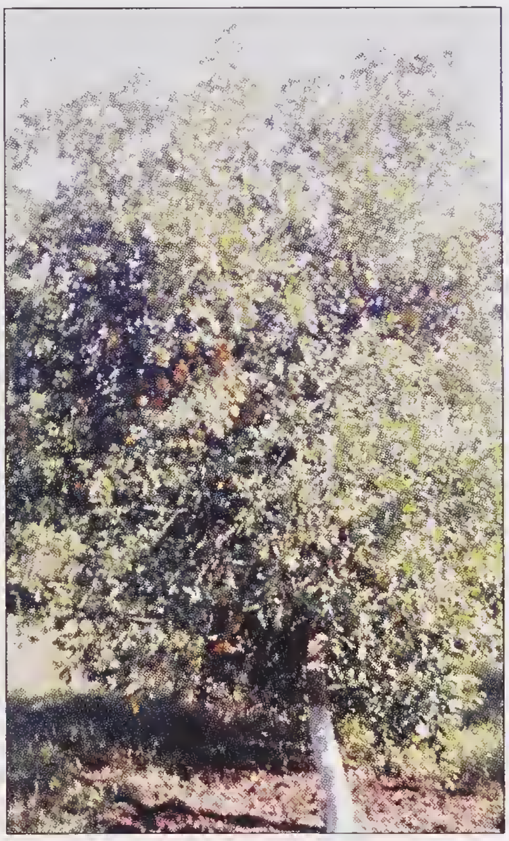


'Pant' Lemon Fruits

Commercial Rootstocks for Citrus

Volkamariana Lemon Tree

Rough Lemon Tree



Rangpur Lime Tree

Cleopatra Mandarin Tree

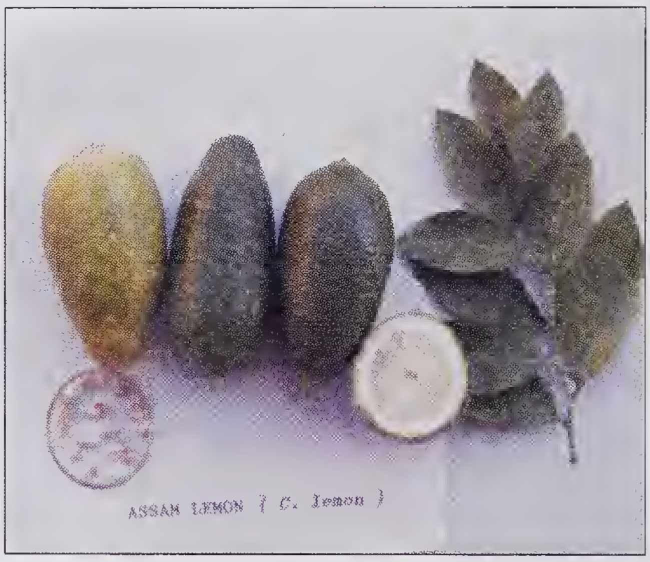
Courtesy: I.P. Singh, NRC for Citrus, Nagpur

Cirtus in the North-Eastern Region

Seedling Mandarin Orchard in Hill Slope

Profuse Bearing in Khasi Mandarin

Grapefruit in Nagaland Village



Assam Lemon of NEH Region

Kachai Lemon of Manipur

Fruited Khasi Mandarin Tree in Homestead

3

Citriculture and Production Technology

CITRUS crops do not grow well in all types of soils and climatic conditions.

Soil and Climate

Citrus crops thrive well in deep, loose, well-aerated soils devoid of any hard pan layers of calcium carbonate in rooting zones. It is highly sensitive to over-moist soil conditions within root zone and defective drainage causes imbalance. Citrus trees are susceptible to salt injury and they cannot thrive well in saline-alkaline soil. Lime induces chlorosis and presence of excessive free lime renders phosphorous, iron, manganese and zinc less available.

Citrus crops, belonging to an evergreen subtropical group, thrive well in frost-free subtropical to semi-tropical climate. Being evergreen, they do not have specific requirement for winter chilling, but cessation of growth activity during winters helps in flower-bud induction, resulting in spring flowering. Different citrus species exhibit a range of tolerance to temperature fluctuations, and total heat during growing season is extremely important for normal growth and productivity of various citrus crops. The light intensity is of principal importance for citrus and temperature plays a key role. Citrus is usually considered as a light-loving plant and the trees are sensitive to shading. Trees exposed to high light intensity usually exhibit paler foliage colour, while those under shade develop deep green foliage. Trees under shade are usually poor fruit yielder and citrus fruits mature early, fruit size is bigger and the acidity development in the fruit juice remains lower. Fluctuation between day and night temperatures intensifies colour development and accentuates sugar accumulation and acid formation.

Site Selection

Proper site selection is very crucial for success of citrus crops. All citrus types cannot grow everywhere. Agroclimatic suitability of different citrus species and varieties are well-defined. Delineation of productive citrus belts in the country had been attempted. Generally, it is concluded that production of citrus is possible under semi-arid to sub-humid tropical climate having red and black soils (Singh, 2001). The soil fertility guide for different commercial citrus cultivars has been adequately described by Srivastava and Singh (2004) (Table 8). Such guides are mandatory to identify soil constraints right at the time of planting of citrus orchards so that soil related constraints are kept at bay in order to harness the

Table 8. Soil fertility guide (derived from DRIS based analysis) for different commercial citrus cultivars of India

	Indices				
Parameter	Deficient	Low	Optimum	High	Excess
Nagpur mandarin (*Citrus reticulata* Blanco)					
pH	<7.2*	7.2–7.5	7.6–8.2	8.3–8.6	>8.6**
Organic C (g/kg)	<0.26	0.26–0.37	0.38–0.62	0.63–0.74	>0.74
N (mg/kg)	<64.7	64.7–94.7	94.8–154.8	154.9–184.9	>184.9
P (mg/kg)	<4.8	4.8–6.5	6.6–15.9	16.0–20.7	>20.7
K (mg/kg)	<64.1	64.1–146.7	146.8–311.9	312.0–394.6	>394.6
Ca (mg/kg)*	<306.1	306.1–408.0	408.1–616.0	616.1–718.0	<718.0
Mg (mg/kg)*	<43.3	43.3–85.1	85.2–163.2	163.3–202.8	>202.8
Fe(mg/kg)	<4.6	4.6–10.9	10.9–25.2	25.3–40.6	>40.6
Mn(mg/kg)	<4.7	4.7–7.4	7.5–23.2	23.3–31.1	>31.1
Cu(mg/kg)	<1.1	1.1–2.4	2.5–5.1	5.2–6.5	>6.5
Zn(mg/kg)	<0.33	0.33–0.58	0.59–1.26	1.27–1.73	>152.1
Yield(kg/tree)	<12.9	12.9–47.6	47.7–117.2	117.3–152.1	>152.1
Khasi mandarin (*Citrus reticulata* Blanco)					
pH	<4.5	4.5–5.0	5.1–6.2	6.2–6.8	>6.8
Organic C (g/kg)	<8.6	8.6–15.6	15.7–32.5	32.6–50.2	>50.2
N (mg/kg)	<82.1	82.1–160.9	161.0–418.7	418.8–547.6	>547.6
P (mg/kg)	<2.3	2.3–4.4	4.5–8.7	8.8–10.9	>10.9
K (mg/kg)	<20.3	20.3–82.2	82.3–287.5	287.6–390.2	>390.2
Ca (mg/kg)	<80.4	80.4–148.7	148.8–285.4	285.5–353.7	>353.7
Mg (mg/kg)	<4.7	4.7–31.2	31.3–84.4	84.5–111.0	>111.0
Fe (mg/kg)	>31.4	31.4–39.4	39.5–180.9	181.0–251.6	>251.6
Mn (mg/kg)	<8.9	8.9–26.9	27.0–80.3	80.4–116.1	>116.1
Cu (mg/kg)	<0.53	0.53–0.66	0.67–2.90	2.91–4.09	>4.09
Zn (mg/kg)	<2.17	2.17–2.83	2.81–5.14	5.15–8.70	>8.70
Yield (kg/tree)	<19.1	19.131.5	31.6–56.3	56.4–68.8	>68.8
Sweet orange (*Citrus sinensis* Osbeck)					
pH	<7.8	7.8–7.9	8.0–8.3	8.4–8.5	>8.5
Organic c(g/kg)	<0.30	0.36–0.48	0.49–0.69	0.70–0.82	>0.82
N (mg/kg)	<62.5	62.5–107.3	107.4–197.2	197.3–242.2	>242.2
P (mg/kg)	<4.9	4.9–8.5	8.6–15.8	15.9–19.5	>19.5
K (mg/kg)	<85.0	85.0–186.3	186.4–389.2	389.3–490.6	>490.6
Fe (mg/kg)	<1.6	1.6–4.7	4.8–17.3	17.4–23.5	>23.5
Mn (mg/kg)	<3.7	3.7–7.6	7.7–15.7	15.8–19.7	>19.7
Cu (mg/kg)	<0.30	0.30–1.75	1.76–4.70	4.71–6.17	>6.17
Zn (mg/kg)	<0.14	0.14–0.43	0.44–1.03	1.04–1.33	>1.33
Yield (kg/tree)	<45.9	45.9–76.5	76.6–137.9	138.0–138.5	>168.5

*Low, **very low

Source: Srivastava and Singh (2004)

productivity potential of a given soil type.

In general, citrus is a shallow feeder and most of the feeding roots are confined to the surface soil. Root spread depends on rootstock also. Root system in vigorous rootstock like Rough lemon is well-developed, whereas that of Trifoliate orange and citranges are generally confined to limited area in soil.

Poor growth of citrus trees has been noticed in soils with high clay and silt, presence of $CaCO_3$ in sub-soil, low contents of organic carbon, available nitrogen, phosphorous and low exchangeable Mg. Poor drainage and soil salinity are other factors affecting citrus crops adversely. Citrus being a nutrient-loving group, adequate availability of both major and micronutrients is a prerequisite for good yield. Planting citrus in hill slopes without adopting any soil conservation measures is highly undesirable. In high rainfall north-eastern hills, erosion of surface soil in hill slopes is one of the major causes of mandarin orange decline.

Propagation

Various types of citrus of commercial importance are propagated differently. While budding is almost universally practised in sweet oranges, grapefruits and mandarin, seedlings are used for limes and mandarin oranges in certain regions. In lemons and sweet lime, air-layering and even cuttings are being used for raising plants. Since seeds of most of the citrus species and cultivars are ployembryonic, nucellar seedlings obtained through seed propagation carry true characters of mother plants, thus enabling to retain the clone characters as in vegetative propagation. The phenomenon of polyembryony also helps in raising uniform rootstock seedlings. For grafting or budding, proper selection of rootstock is of highest importance. The availability of a large number of graft compatible species and cultivars has made the choice of proper rootstock broader as well as complex. Rootstocks are known to impart marked effects on vigor, precocity, productivity, physicochemical characteristics of fruits, longevity of trees, disease resistance, adaptability to soil-climatic conditions, etc. Due

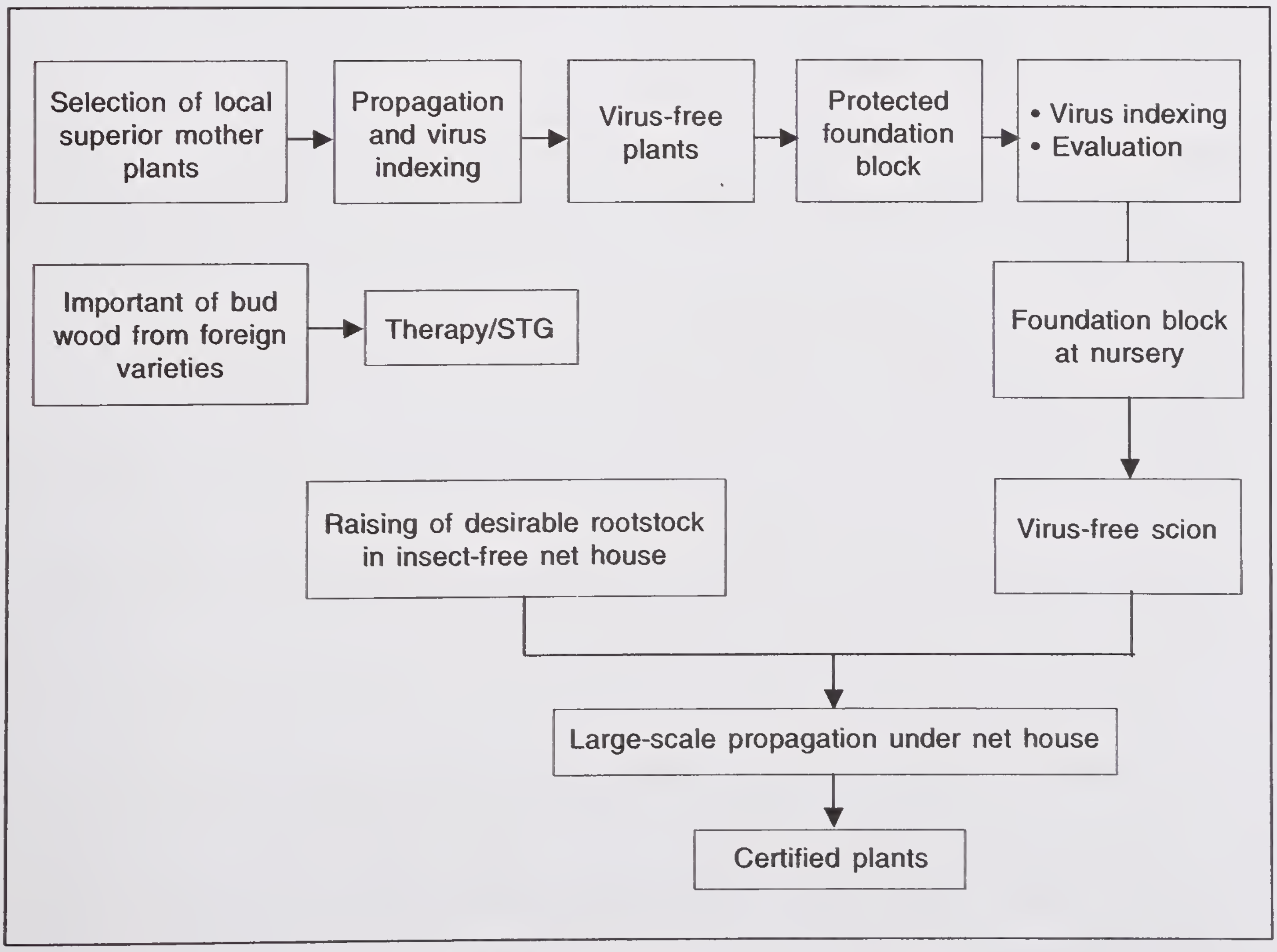

Selection of local superior mother plants
Propagation and virus indexing
Virus-free plants
Protected foundation block
• Virus indexing
• Evaluation
Important of bud wood from foreign varieties
Therapy/STG
Foundation block at nursery
Raising of desirable rootstock in insect-free net house
Virus-free scion
Large-scale propagation under net house
Certified plants

Fig. 5. Bud wood certification system in citrus

to the presence of certain citrus viruses, bud-wood certification programme through identification of disease-free mother (donor) trees for scion wood and maintenance of nursery hygiene have become very important in raising of propagating materials for citrus. The bud wood certification programme suggested by National Research Centre for Citrus, Nagpur is shown in Fig. 5.

Some of the commonly used rootstocks are rough lemon, trifoliate orange, citranges and Rangpur lime. The important characteristics of a few common rootstock have already been indicated (Table 6).

Different types of budding like Patch or Forkert or T-budding may be followed with high rate of success. The time of budding varies from place-to-place. The right stage of budding is that when plants have good sap flow and cambium tissue is highly active. Well-swollen, un-sprouted buds, from about one-year-old non-angular branches are preferred, and presence or absence of small portion of wood along with individual bud does not really matter for the success in bud union. Budding should preferably be done at a height of about 20–25 cm from the ground level and usually become ready for orchard planting 6–9 months after budding.

In lemons, sweet lime and citron, cuttings and layering (air-layering) are commonly employed and plants with shallow but good root system are multiplied. In lemon, cuttings from middle portion of one-year-old shoots are rooted better. The air-layering is usually done during early rain. The propagating material becomes ready in about 3 months. After removal from the mother plants, it is preferable to keep the layers in nursery-bed for about a month before final transplanting at the orchard site. For certain specific advantages, however, budding on desired rootstocks may also be followed for these species as well.

Raising Nucellar Seedlings in Mandarins and Acid limes

For raising healthy planting material from seeds, following steps are taken:

Step I: Selection of mother plants

As selection criteria following broad parameters may be considered:

- Tree age : 20–25 years or above.
- Tree health : Non-chlorotic, lush green dense foliage. No dried twigs and apparent symptoms of any disease ideal.
- Tree productivity: Regular bearing with 1,000 fruits and above.

Step II: Collection of seeds and nursery raising

- Procure sufficient number of fruits from selected mother trees at harvesting time.
- Extract healthy, fully developed seeds from fruits, wash them with clean water (with rubbing in ash to make free from pulp if needed) and dry them under shade.
- Treat the seeds with captan/thiram (1 g/kg of seeds) to avoid infection.

- Sow seeds as early as possible after extraction and preferably within 7 days. For raising healthy seedlings sow the seeds in plastic tray (60 cm × 40 cm × 12 cm size).
- For drainage of excess water, there should be at least 6 holes in the bottom of trays. Fill the trays with sterilized soil mixture (one part of fertile soil collected from virgin areas where there is no citrus tree + 2 parts sand) and keep the trays at least one feet (30 cm) height from the ground on bricks/stones.
- Seeds are shown at a depth of 1–1.5 cm with a spacing of 2.5–3.0 cm in rows. After sowing light shower irrigation should be given with water can.
- Germination starts 20–25 days after sowing. Optimum soil temperature is between 80–90°F but even 55°F is enough for good germination.
- Protect the emerging seedlings with some shelter either by plastic cover or shade nets (50% shade).
- Seedlings when 4–6 cm tall having 8–10 leaves are ready for transplanting in polybags, filled with sterilized soil mixture.
- Discard all markedly smaller or too taller seedlings to ensure uniform neceller seedlings before transplanting to polybags. Seedlings from primary nursery (trays) to be uprooted with fork carefully to minimize root damage. The selected seedlings should preferably be treated with Rhidomil (2.75 g/litre water) and twisted (hook-necked) tap roots should be avoided for secondary nursery (polybags).

Planting

Usually, citrus is planted in pits of 50 cm × 50 cm × 50 cm or 75 cm × 75 cm × 75 cm size in square system with a spacing of 5–8 m depending upon the species. For acid lime (*Citrus aurantifolia*), a spacing of 5 m × 5 m is adequate. For pummelos and vigorous rootstocks like rough lemons wider spacing is usually recommended. Mandarin orange being more or less upright in growth habit, particularly when raised from seeds can be planted at a distance of 5–6 m. Though planting is usually done during the monsoon season, it is better not to plant at the time of heavy rains to avoid any waterlogging near the planting pits. Weather should not be too wet or too dry at the time of planting. In lanky propagating plants, staking should be done. At post-monsoon period, plant bases may be covered with mulches so as to conserve moisture in rooting zone. Supplementary irrigation in the early years of planting is essential during dry months.

Irrigation

Irrigation is of vital importance to citrus orchards. It is considered as one of the most critical cultural operations. The coarse-textured sand or sandy loam soils store less water and hence in such soils more frequent irrigations are required. In finer-textured clayey or silty soils, on the other hand, more water is required to wet but frequency of irrigation should be less. In addition to soil type, irrigation requirement depends on species, rootstock, age, bearing capacity, topography, watertable position, rainfall, atmospheric humidity, temperature, etc. In deciding irrigation application in citrus, following points need to be considered (Ghosh, 1996):

- About 60–80% of root activity in citrus crops is confined to first 60 cm top soil and citrus roots spread far beyond the vegetative spread of trees. The zone of water application is important and required to be standardized for irrigation economy.
- During the periods of rapid growth, flowering and fruit setting, citrus trees are sensitive to moisture stress. The fruit size usually gets reduced if moisture deficiency occurs frequently when developing fruits are on trees. During spring and summer months, soil may be allowed to dry out somewhat but wilting should be avoided during blooming and fruit setting. Stress during early fruit development period (April–June in northern and October–December in southern hemispheres) causes excessive fruit abscission.
- Citrus trees are highly sensitive to excess moisture and waterlogging conditions. They require good soil aeration, and excessive irrigation may result in poor soil aeration leading to reduced growth and yield, predisposing the trees to root rot and other diseases. Excess irrigation also results in leaching of essential nutrients from soil as well as in accumulation of certain undesirable salts if irrigation water is not of good quality. Citrus trees are sensitive to salinity. The total soluble salts in irrigation water should not exceed 1,000 ppm. Over-irrigation of citrus causes decline of orchards in many cases.
- While irrigating, care should be taken so that the irrigation water does not touch the tree truck directly and a dry area needs to be maintained near the tree trunk. Saturation of soil beneath the canopy and direct contact of irrigation water with the trunk may predispose the trees to root rot (*Phytophthora* sp.) and other disease. Waterlogging, particularly, near the tree trunk, can be avoided by providing mounds of earth around the tree trunk well below the bud union.

Time and Quantity of Irrigation

Irrigation should not be held back till usual wilting symptoms are apparent. Determination of soil moisture content of the areas occupied by roots gives a fairly accurate indication of irrigation need. Systematic trials conducted in USA and other countries indicate that maximum fruit yield can be obtained by minimizing or preventing moisture stress, particularly during first part of growing season, including fruit setting period. The amount of moisture stress during latter part of growing season, however, increases soluble solids and vitamin C in fruit juice. Studies conducted in India indicate irrigation scheduling in clayey loam soil results in optimum yield and growth of Nagpur mandarin orange under hot and dry climatic conditions. In Maharashtra, 8-year-old Nagpur mandarin trees given with moderate quantity of irrigation (1,500 litres/tree) applied at 120 cm from tree trunk gave better-sized fruits and higher yield.

Irrigation requirement of citrus in NEH

Even for high rainfall north-eastern region, supplementary irrigation during dry November–March appears to be essential as revealed by the research findings of ICAR Research Complex for NEH Region, Barapani (Meghalaya). The results are given in Table 9.

Table 9. Irrigation requirement of mandarin orange in north-eastern region

Season	Period	Tree canopy with ground coverage	
		Above 70%	About 50%
Pre-monsoon	January–March	132.9 mm	105.9 mm
Monsoon	April–October	20.8 mm	8.4 mm
Post-monsoon	November–December	53.9 mm	44.6 mm
Full year	January–December	207.6 mm	158.8 mm

Water requirement of mandarins at different stages

Water requirements estimated at NRC for Citrus, Nagpur, for Nagpur mandarin and at Punjab Agricultural University (PAU), Ludhiana, for Kinnow mandarin as indicated clearly established the importance of proper water management in citrus (*see Box*).

Variety	Quantity (mm/year)
Nagpur mandarin	651 for young (1–3 years) plants, 849 for middle-aged (5–8 years) plants, 997 for mature trees (above 10 years)
Kinnow mandarin	615 for 6 years old plants

Nutrition and Fertilization

Citrus is a nutrient-loving plant. About 15 elements play important role for proper growth and development. In addition to major nutrients like N, P, K, Ca, Mg and S, citrus requires micronutrients like Zn, Cu, Mn, Fe, B, Mo, etc. Inadequate plant nutrition causes serious disorder in citrus and may eventually lead to decline of orchards. Extensive work has been done on mineral nutrition in citrus. Chapman *et al.* (1945) reported that about 18 tonnes of citrus fruits need about 21 kg nitrogen, 5 kg phosphorus, 41 kg potassium, 19 kg calcium, 3.6 kg magnesium, 2.3 kg sulphur, 40 g boron, 9 g copper, 50 g iron, 13 g manganese and 13 g zinc.

Foliar diagnosis is widely used as a reliable tool for determining nutritional status of citrus orchards. Leaf nutrient standards have already been worked out in India. Some of the standards for different citrus types (mandarins, sweet orange and acid lime) compiled by Srivastava and Singh (2004) and Varalakshmi and Bhargava (1998) are shown in Table 10. Such

Table 10. Leaf nutrient indices (derived from DRIS-based analysis) for different commercial citrus cultivars in India

Nutrient	Indices				
	Deficient	Low	Optimum	High	Excess
Nagpur mandarin					
N (%)	< 1.12	1.12–1.69	1.70–2.81	2.82–3.38	> 3.38
P (%)	< 0.06	0.06–0.08	0.09–0.15	0.16–0.19	> 0.19
K (%)	< 0.22	0.22–1.01	1.02–2.59	2.60–3.38	> 3.38
Ca (%)	< 1.1	1.1–1.79	1.80–3.28	3.29–4.02	> 4.02
Mg (%)	< 0.31	0.31–0.42	0.43–0.92	0.93–1.38	> 1.38
Fe (ppm)	< 55.6	55.6–74.8	74.9–113.4	113.5–132.7	> 132.7
Mn (ppm)	< 40.2	40.2–54.7	54.8–84.6	84.2–98.7	> 98.7
Cu (ppm)	< 5.9	5.9–9.7	9.8–17.6	17.7–21.5	> 21.5
Zn (ppm)	< 5.5	5.5–13.5	13.6–29.6	29.7–37.7	> 37.7
Yield(kg/tree)	< 12.9	12.9–47.6	47.7–117.2	117.3–152.1	> 152.1
Khasi mandarin					
N (%)	< 1.67	1.67–1.96	1.97–2.56	2.57–2.85	> 2.85
P (%)	< 0.06	0.06–0.08	0.09–0.10	0.11–0.13	> 0.13
K (%)	< 0.52	0.52–0.98	0.99–1.93	1.94–2.40	> 2.40
Ca (%)	< 1.72	1.72–1.96	1.97–2.49	2.50–2.75	> 2.75
Mg (%)	< 0.14	0.14–0.23	0.24–0.48	0.48–0.54	> 0.54
Fe (ppm)	< 22.6	22.6–84.5	84.6–249.0	249.1–331.3	> 331.3
Mn (ppm)	< 18.6	18.6–41.5	41.6–87.6	87.7–110.6	> 110.6
Cu (ppm)	< 1.83	1.83–2.12	2.13–14.4	14.5–20.6	> 20.6
Zn (ppm)	< 11.1	11.1–16.2	16.3–26.6	26.7–31.8	> 31.8
Yield(kg/tree)	< 19.1	19.1–31.5	31.6–56.3	56.4–68.8	> 68.8
Sweet orange 'Mosambi'					
N (%)	< 1.28	1.28–1.97	1.98–2.57	2.58–2.68	> 2.68
P (%)	< 0.050	0.050–0.090	0.091–0.17	0.18–0.21	> 0.21
K (%)	< 1.12	1.12–1.32	1.33–1.72	1.73–1.92	> 1.92
Ca (%)	< 1.09	1.09–1.72	1.73–2.98	2.99–3.62	> 3.62
Mg (%)	< 0.13	0.13–0.31	0.32–0.69	0.70–0.87	> 0.87
Fe (ppm)	< 25.9	25.9–69.4	69.5–137.1	137.2–200.1	> 200.1
Mn (ppm)	< 29.7	29.7–42.1	42.2–87.0	87.1–159.5	> 159.5
Cu (ppm)	< 2.0	2.0–6.5	6.6–15.8	15.9–20.5	> 20.5
Zn (ppm)	< 9.0	9.0–11.5	11.6–28.7	28.8–37.3	> 37.3
B (ppm)	< 7.8	7.8–12.7	12.8–23.1	23.2–43.8	> 43.8
Mo (ppm)	< 0.28	0.28–0.38	0.39–1.1	1.2–1.5	> 1.5
Yield(kg/tree)	< 45.9	45.9–76.5	76.6–137.9	138.0–168.5	> 168.5
Acid lime					
N(%)	< 1.24	1.24–1.52	1.53–2.10	2.1–2.39	>2.39
P(%)	< 0.07	0.07–0.09	0.10–0.15	0.16–0.18	>0.18
K(%)	< 0.60	0.60–0.95	0.96–1.66	1.67–2.01	>2.01
Ca(%)	< 2.85	2.85–3.04	3.05–3.43	3.44–3.63	>3.63
Mg(%)	< 0.16	0.16–0.39	0.40–0.60	0.61–1.10	>1.10
S(%)	< 0.21	0.21–0.24	0.25–0.29	0.29–0.31	>0.31
Fe(ppm)	< 77.0	77.0–116.0	117.0–194.0	195.0–234.0	>234.0
Mn(ppm)	< 10.0	10.0–20.0	21.0–63.0	64.0–85.0	>85.0
Cu(ppm)	< 5.61	5.61–8.67	8.68–14.8	14.9–17.8	>17.8
Zn(ppm)	< 16.0	16.0–24.0	25.0–50.0	51.0–200.0	>200.0
Yield (tonnes/ha)	< 13.7	13.7–15.6	15.7–19.4	19.5–21.35	>21.35

Source: Srivastava and Singh (2004), Varalakshmi and Bhargava (1998).

cultivar-specific nutrient diagnostics have proved very effective in developing constraint based citrus fertilization programme so that nutrient mining emerging out of a large difference between nutrient added to what is required by crop annually, is checked and quality production along with enhanced orchard longevity is maintained.

Foliar deficiency symptoms are also conspicuous in some of nutrients (Table 11).

Table 11. Foliar deficiency symptoms of macro and micronutrients

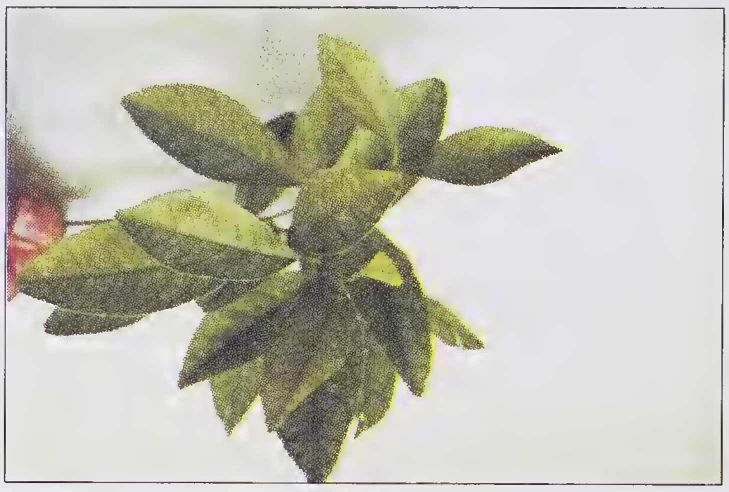
Nutrient	Deficiency symptoms
Nitrogen	Symptoms appear on older leaves and proceeds towards the younger leaves. Yellowing of foliage over the entire tree, light green colour smaller sized new leaves and leaf shedding in advanced stage.
Phosphorous	Older leaves loose their deep green colour, become lustless and become some what purplish or bronze coloured.
Potassium	Sparse foliage, somewhat bronzed appearance of leaves and weak new latest shoots.
Zinc	Interveinal chlorotic symptoms with irregular green bands along the midrib and necrotic young growth common. In acute stage, narrow pointed leaves of much reduced size noticed.
Iron	Interveinal white chlorosis on young leaves and in some cases complete bleaching of leaf lamina and scorching of leaf margins and tips.
Manganese	Mottled chlorosis with green veins and yellow leaf web tissue on older leaves.
Boron	Terminal leaves turn necrotic and shed prematurely. Shortening of internodal length in terminal shoots and rosetty appearance in acute deficiency condition.

The fertilizer schedule recommended for different citrus varieties in different states of India and fertilizer doses for mandarin orange in major mandarin orange-growing areas are given in Tables 12 and 13.

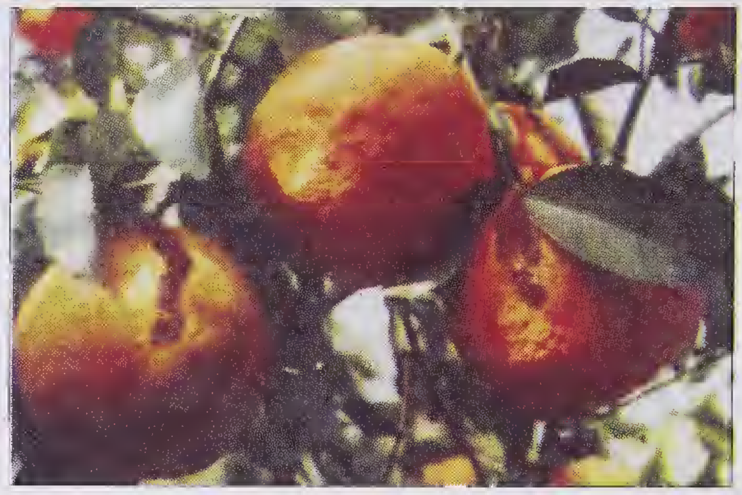
Intercropping

In the early stages of establishment of a citrus orchards till bearing the interspace can be economically utilized with short duration crops, preferably of leguminous types. As far as practicable, the intercrops should be shallow rooted, of short duration, should have good canopy cover to protect the soil from erosion, profit yielding and non-soil depleting types. Planting of leguminous vegetables like pea, cowpea, gram, beans increased the leaf N content of mandarin orange and thereby tree vigour and yield. Crops like sugarcane, ginger, turmeric, fodder berseem, cotton were found to adversely affect citrus in the long run and should therefore, be avoided.

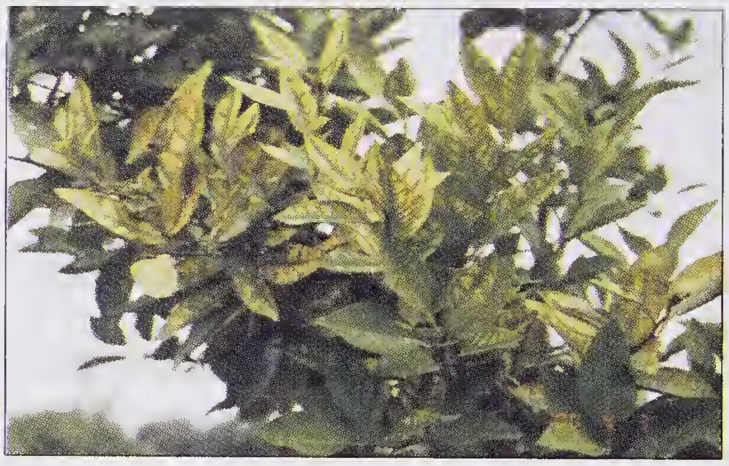
Important Nutritional Disorders in Citurs



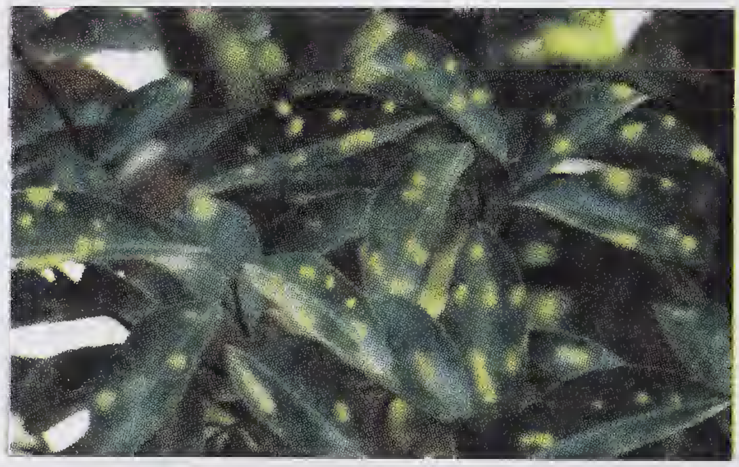
Mn deficiency: Network of green veins in chlorotic background



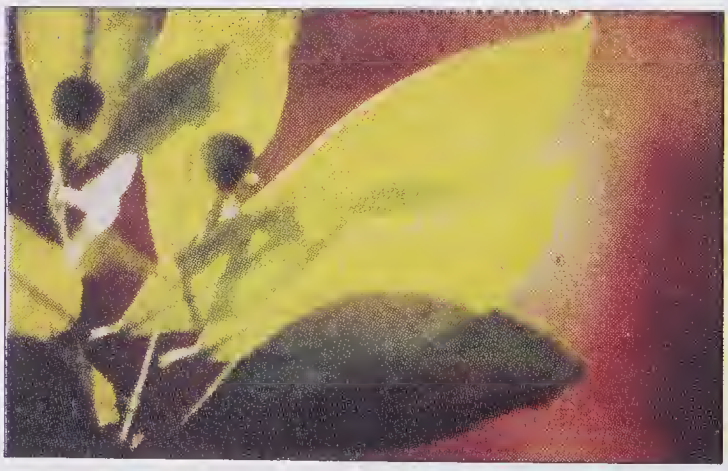
Cu deficiency: Gum oozing



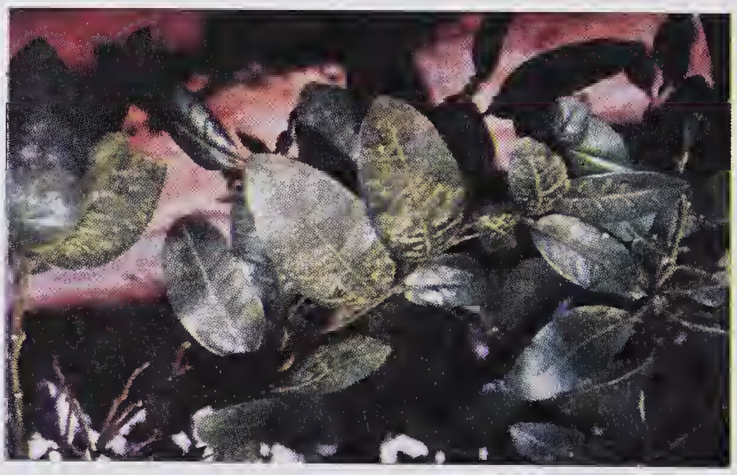
Zn deficiency: Interveinal chlorotic blotches, pointed and rosette leaves



Mo deficiency: Yellow spots



Fe deficiency: Chlorotic paper leaves



Fe toxicity: Accretions along mid-rib and veins

Courtesy: A.K. Srivastava, NRC for Citrus, Nagpur

Table 12. Fertilizer recommendations for optimum productivity of different citrus cultivars

Scion	Rootstock	Recommended fertilizer (g/tree)			Yield, no. of fruits/tree
		N	P_2O_5	K_2O	
Punjab: (Bhatinda) Kinnow	Rough Lemon	400	200	400	713
Jaffa orange	Rough Lemon	400	200	400	292
Assam:					
Khasi mandarin	Rough Lemon (Sohmyndong)	300	250	300	–
Maharashtra: (Nagpur)					
Nagpur mandarin	Rough Lemon (Jambhiri)	600	200	100	659
Acid Lime	Seedling	800	200	100	67,5
Karnataka: (Gonicoppal)					
Coorg mandarin	Rangpur Lime	400	200	200	500
Andhra Pradesh: (Tirupati)					
Sathgudi		400	200	200	500
Tamil Nadu: (Periyakulam)					
Acid lime	Seedling	600	200	300	115.7 (kg/tree)

Source: All India Coordinated Research Project on Tropical Fruits (1982–89).

Table 13. Fertilizer doses for mandarins in different regions

Region	Variety	Recommended dose (g/tree)		
		N	P_2O_5	K_2O
Assam	Khasi mandarin	300	250	300
Karnataka	Coorg mandarin	400	200	200
Maharashtra	Nagpur mandarin	600	200	400
Punjab	Kinnow	400	200	400

Pest and Disease Management

Pests

Citrus psylla

- **Symptoms:** Psylla nymphs (*Diaphorina citri*) damage buds and soft young leaves, causing leaf distortion and curling. Both nymphs and adults suck plant sap from leaves, buds and tender shoots. The nymphs secrete whitish crystalline honey dew which helps sooty mould growth. The insect acts as the vector for greening disease.
- **Control:** Spraying with malathion (0.05%), monocrotophos (0.75 ml), quinalphos (1 ml) or dimethoate (1 ml) per litre of water or soil application of dimethoate @ 6 ml a.i./tree is effective in checking its infestation. Azadirachtin (0.03%) and neem oil also controls it.

Citrus leaf miner

- **Symptoms:** Citrus leaf miner (*Phyllocnistis citrella*) larvae feed on epidermis of tender leaves making serpentine mines which are characteristically silvery in colour due to entrapped air. The affected foliage eventually dry up and fall down. It is a serious pest in nursery and damages all citrus species.

- **Control**: The best strategy of defence was based on the alternate use methomyl, flufenoxuron and white mineral oil, petroleum oil sprays at 0.25–0.5%. Synthetic pyrethroids especially fenvalerate is found quite effective. Soil drenching with lindane @ 15 kg/ha and foliar spraying of Ekaliex (1.5 ml/litre) reduces it significantly.

Citrus blackfly

- **Symptoms:** Blackfly (*Aleurocanthus woglumi)* is one of the economically important insect pests of citrus in central India. It is an endemic pest and was a devastating epidemic of pest on Nagpur mandarin during the mid-seventies that put the citrus industry of central India in doldrums. Both nymphs and adults suck cell sap and nymphs excrete honeydew on which sooty mould (*Capnodium* sp.) grows resulting formation of black layer covering entire plant including that hinders photosynthesis and is locally called as 'Kolshi' in Vidarbha.
- **Control:** Monocrotophos (0.06%) and oxydemeton-methyl (0.05%) are most effective against CBF nymphs. Spraying with monocrotophos @ 1 ml/litre or dimethoate (2 ml/litre) of water on lower side of leaves is suggested. Biological control by predators (*Serangium percesetosum* and *Anisochrysa boninensis*) and parasites is possible partially.

Lemon butterfly

- **Symptoms:** Lemon butterfly (*Papilio demoleus* Linn) is most destructive to citrus seedlings as well as to new flush. The pest may cause complete defoliation. The fully-grown caterpillars are about 4–5 cm long and green in colour.
- **Control:** Hand-picking has been earlier recommended as a control measure. Foliar sprays of any of insecticides, viz. dimethoate @ 1.5 ml, fenitrothin 1 ml, carbaryl 2 g or endosulfan 1.4 ml/litre of water at an early larval stage can effectively check the pest infestation. Methyl-parathion (0.05%), methamidophos (0.05%) and leptophos (0.06%) are most effective and persistent insecticides.

Citrus aphids

- **Symptoms:** Citrus aphids (*Toxoptera* sp.) infest the lower surface of leaves, tender shoots and young fruits. Adults and nymphs suck the cell sap from tender leaves and shoots, resulting in devitalization of plants. Affected leaves in severe cases curl up and get deformed, finally the growth of young shoots is effected.

  Citrus tristeza virus (CTV) is transmitted by various aphids species, viz. *T. citricida, A. gossypii, A. craccivora, Doctynotus jassae* and *T. aurantii.*

- **Control:** Foliar sprays of 0.02% methyl demeton, monocrotophos, quinalphos, dimethoate or malathion 0.05% at weekly intervals control the pest effectively. Mahua (*Madhuca indica*) and Pongamia (*Pongamia glabra*) oils (1%) and neem and pongamia seed extracts (2%) are also recommended for aphid control.

Mealy bug

- **Symptoms:** The body of mealybug (*Planococcus citri* Risso) is covered with white mealy wax. Nymph and female mealy bug usually feed underside of leaves, causing heavy damage to nursery and grown-up plants and also attack the base of the fruits near the stock end resulting in heavy fruit drop.
- **Control:** Sticky bands should be placed on trunk portion of tree to desist the crawlers from climbing on trunk. Raking the soil around trunk during summer months helps in the desiccation of eggs and also in exposing mealy bugs to natural enemies. Spraying of dimethoate 150 ml + Kerosene oil 250 ml in 100 litres of water or carbaryl 10 ml + kerosene oil 10 ml or malathion 20 ml in 10 litres of water checks mealy bugs effectively. Maximum reduction in pest population, however, is obtained using methidathion (0.1%).

A mixture of neem oil and *Pongamia pinnata* oil (4%) also controls of *P. citri*.

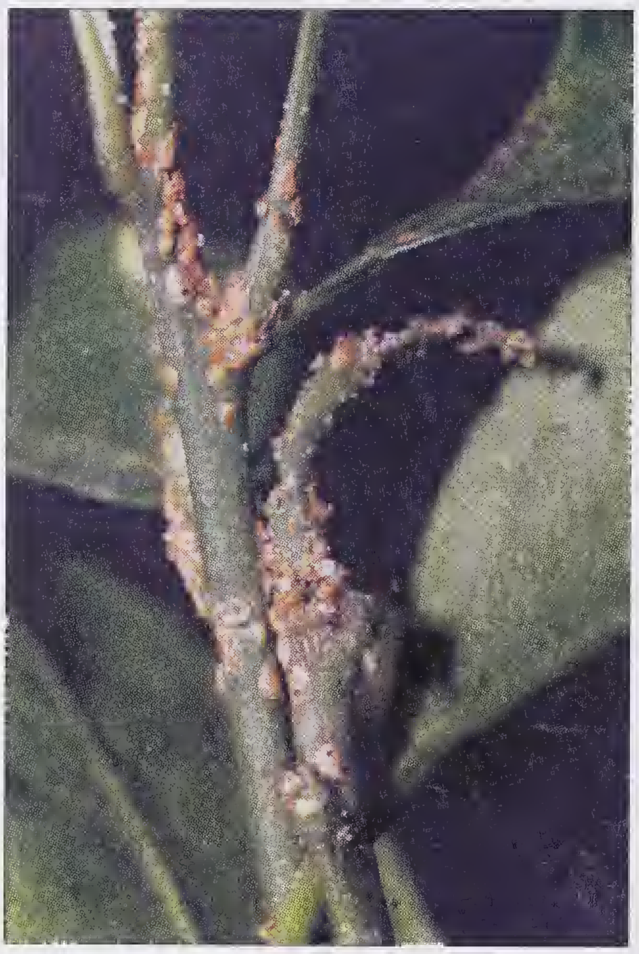
Bark-eating caterpillar

- ***Symptoms:*** Infestation of bark-eating caterpillar (*Inderbela* spp.,) is usually confined to neglected orchards. Grubs make holes in stems for hiding and feed on the bark portion during evening and nights. Presence of silken threads, frass and excretal pellets are noticed.
- ***Control:*** Bark-eating caterpillars can be easily controlled by inserting a cotton swab soaked in kerosene/petrol and plugging it by mud or injecting a few ml of monocrotophos or dichlorvos (0.1%) in each tunnel. Spraying on affected portion with the same solution after clearing the larval excreta and wooden frass once during September–October and again in January–February is recommended.

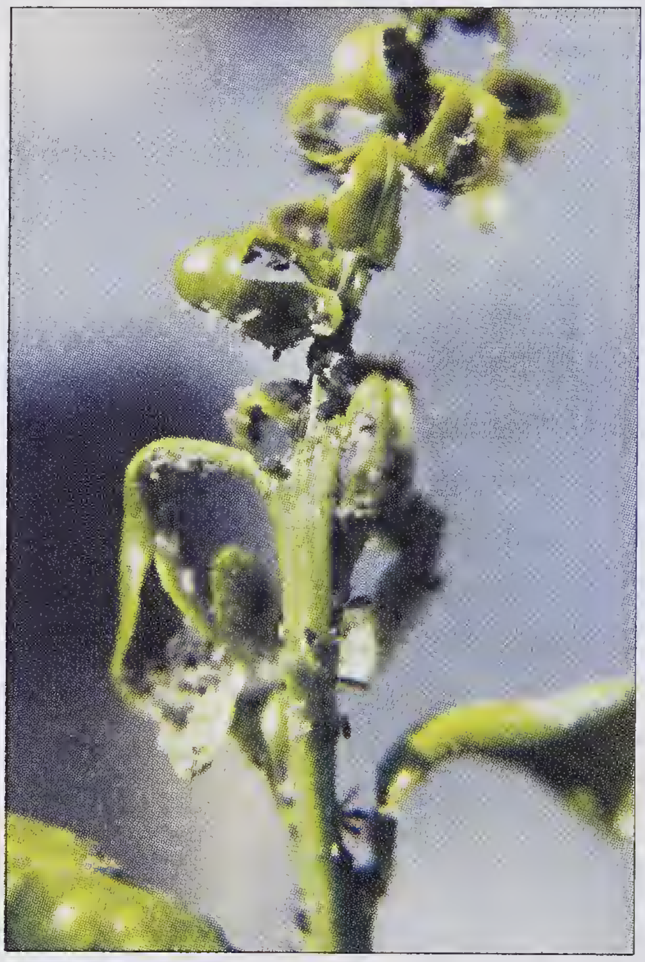
Trunk- and stem-borer

- ***Symptoms:*** Grub of trunk- and stem-borer (*Monohammus versteegi* Ritsema) bores into pith generally at the base of the trunk and kills the tree within 3–6 years of growth. About 20–30% mortality in young orchards has been recorded from Meghalaya and Arunachal Pradesh. Due to its infestation, presence of sawdust like frass material over branches are main symptoms.
- ***Control:*** Soil working 6–8 cm, deep around trees (0.5 m diameter) and treating with 5% aldrin or BHC dust @ 100–150 g/tree helps in checking its attack. Injection of 3–5 ml of petrol or carbon disulphide or chloroform into bored hole through a syringe and plugging the

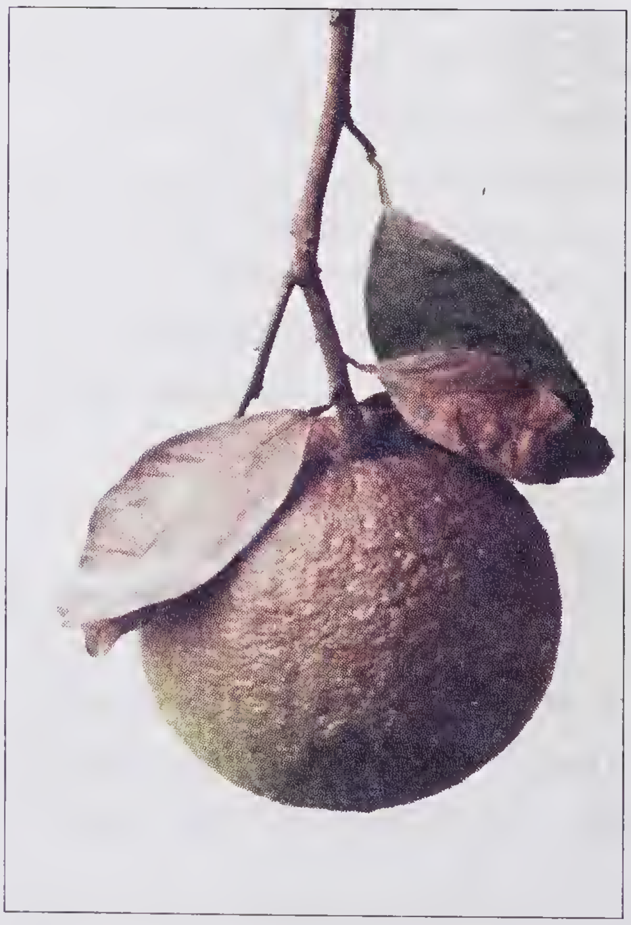
Major Insect Pests of Citrus



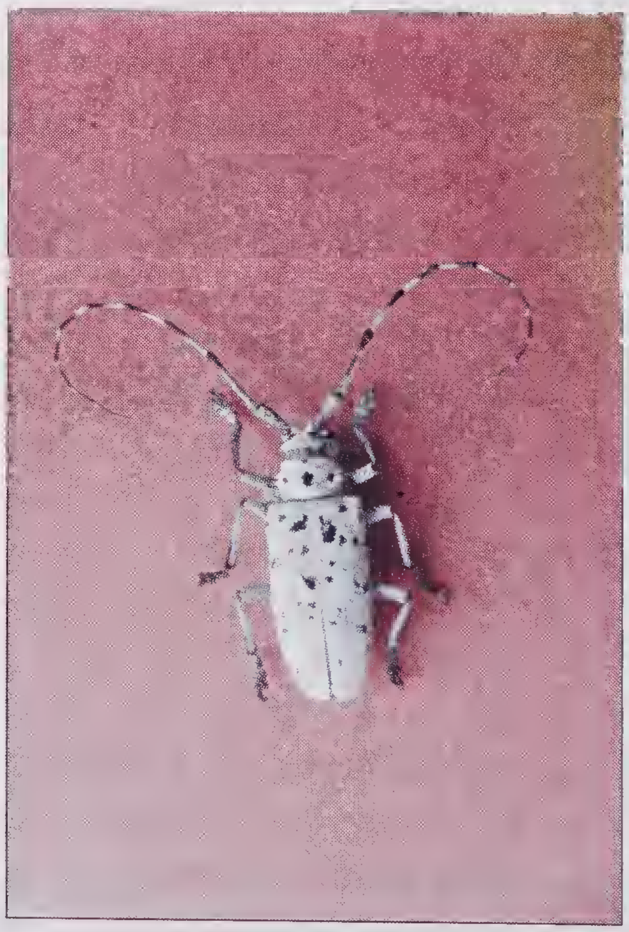
Citurs Psylla Infestation



Aphid Infestatoin



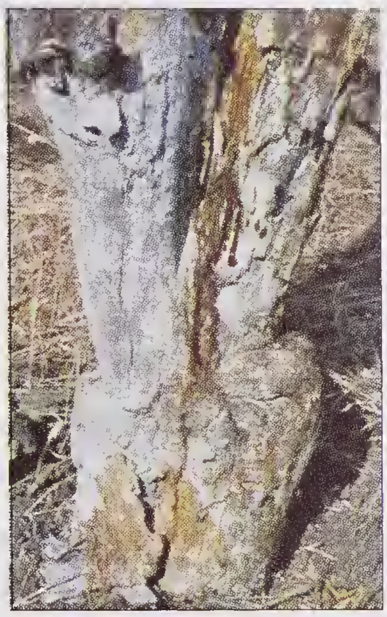
Black fly (Kolshi) Infestation

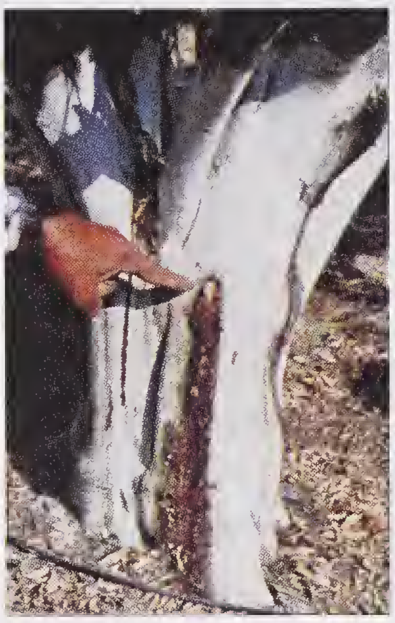


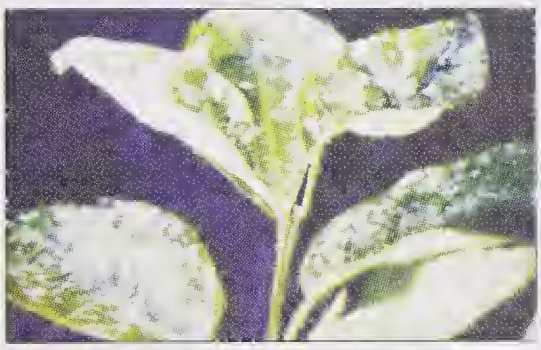
Citrus Trunk-Borer

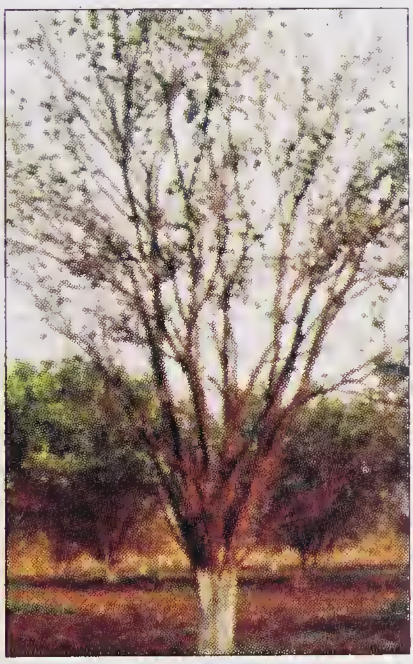
Courtesy: V.J. Shivankar, NRC for Citrus, Nagpur

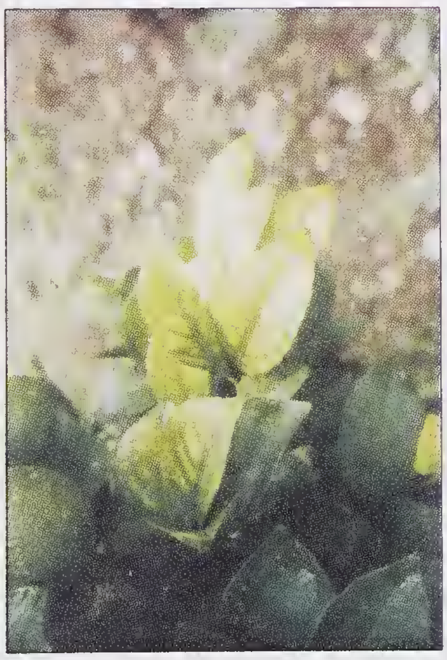
Major Diseases of Citrus

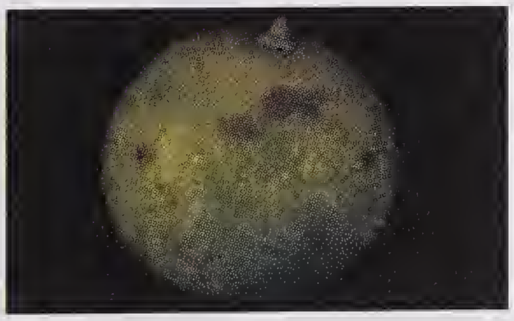

Phytophthora Foot Rot in Nagpur Mandarin

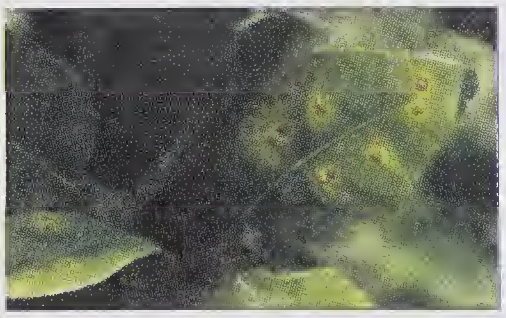

Phytophthora Gummosis


Powery Mildew in Khasi Mandarin


Dedining Nagpur Mandarin due to Phytophthora infection


Citrus Greening in *Mosambi* Sweet Orange


Citrus Canker in Acid Lime Fruit


Citrus Canker in Acid Lime Leaf

Courtesy: A.K. Das, NRC for Citrus, Nagpur hole with wet soil or wetting a swab of cotton with these agents and then inserting it in the larval hole and then plugging with wet soil are recommended.

Fruit-sucking moth

- ***Symptoms***: The adults of pests (*Otheris* sp., *Achaea* sp. and *Ophederes* sp.) puncture the maturing orange fruits and feed the juice. Such fruits drop to the ground and rot.
- ***Control:*** The pest can be controlled through:
  - Poison baiting with 20 g malathion WP or 50 ml diazinon + 200 g *gur* with some vinegar or fruit juice in 2 litres of water (good enough for 25–30 trees) has been found to be effective. Poison baits can also be prepared by mixing 100 g of crushed orange fruit + 1.0 g Padan 50 SP + 10 g of *gur* and 5 drops of vinegar. This bait should be put in earthen pots and hung on orange trees for attracting and killing the fruit-sucking moth.
  - Spray Labaycid 50 EC or Diazinon 60 EC (2.0 ml/litre of water) to weeds/wild plants around the orchard where the pests are found in young stage.
  - Destroy fallen fruits and practise clean cultivation.
  - Use light traps to collect the moth.

In premature fruit drop due to attack of fruit fly caused by *Dacus dorsalis*, insect baits containing malathion or trichorfon or fenthion 0.05% + 1% crude sugar 2 months before fruit repening is effective. Use of 25 traps/ha starting 2 months before harvesting and thereafter replacing with fresh solutions after every 7 days is sufficient.

Nematodes

- ***Symptoms:*** Citrus nematode (*Tylenchulus semipenetrans*) is found to be associated with trees showing decline symptoms. In addition to this, *Radopholus similies* and other nematode fauna also predispose the plants to declining malady.
- ***Control:*** Citrus rootstocks like trifoliate orange and its hybrid CRH–41 are found to be resistant to *T. semipenetrans*. Integration of neem cake with *Paecilomyces lilacinus*, a parasitic fungus or *Glomus fasciculaium*, an arbuscular mycorrhizal fungus, is reported to be effective in reducing nematode population in soil and root.

Dichlorofenthion @ 45 ml/ha, Ethoprophos @ 40 kg a.i/ha and Fensulfothion @ 30 kg a.i/ha are highly effective in controlling citrus nematodes.

Disease

Phytophthora disease

Symptoms: Causes foot rot, root rot, crown rot, gummosis, leaf fall and death of the tree. Foot rot lesions develop as high as 60 cm from the ground level in the tree trunk and may extend below the soil on the roots.

On scrapping the dead bark of the lesions, a brown, discoloured, slippery area can be seen. Such active lesions start oozing gum which can be seen on the trunk as brownish black oozing known as gummosis. In dry season, dead bark becomes firm, breaks away from healthy bark, curls and splits. In severe cases, when foot area and significant portion of root system is damaged, the large branches of the same side of the affected plant are killed due to the rot of the conducting tissues near the bark. Heavy and poorly drained soil, excessive moisture in the rooting zone, prolonged contact of water with tree trunk predispose the tree to *Phytophthora* disease.

Control

- Soil should be kept well-drained and no stagnation of water at tree trunk to be allowed.
- Injuries to trunk and root system during ploughing and interculture operation to be avoided.
- Foot rot or gummosis affected portion should be scraped out with a sharp knife taking care not to damage the wood before application of Bordeaux paint (1 : 2 : 3 linseed oil).

Spraying *Phytophthora* infected plants two times (first at onset of monsoon and second after 40 days) and soil drenching with Ridomil MZ–72 (2.75 g/litre of water) or Aliette (2.5/per litre of water) may control the disease.

Tristeza (Quick decline)

- ***Symptoms:*** Tristeza (a word that described the sad appearance of a tree) virus caused damage to citrus industry in many countries. The disease causes quick decline of trees, leaves develop various deficiency symptoms, and leaf falling, root decay, twig die back and ultimate death of the tree are also conspicuous. Affected trees have a tendency to blossom heavily in off-season. Specific symptoms of tristeza infection are honeycombing, pitting of inner face of the bark of the trunk, severe pitting develops in species like lime, citron, sweet orange, mandarin orange, rough lemon, sweet lime, etc. The definite test for presence of tristeza requires greenhouse assay through indexing on indicator plants like Indian Kagzi lime, Mexican lime, etc. where definite symptoms of vein clearing and stem pitting confirm the virus.
- ***Control:*** The disease can be kept under control by use of tolerant rootstocks, such as rough lemon, sweet orange, Cleopatra mandarin, Rangpur lime, trifoliate orange, citranges, etc. The bud wood to be used for propagation should be free from viruses and through insecticidal spray the aphid (vector) population can be reduced considerably.

Greening

- ***Symptoms:*** Greening disease is widespread in many species of citrus

and is considered by many as the most serious disease in mandarins. The disease is caused by a bacterium. The infected plant shows chlorosis of leaves resembling zinc deficiency (sometimes dotted with green islands), thickening of leaf blade and shortening of twig internodes, off-season blooming, leaf shedding and die back. Fruits of the infected trees are usually small-sized, lopsided, remain green for longer period, contain curved columellas, aborted seeds and fall prematurely.
- **Control** The disease can be spread through bud wood and the insect vector, citrus psylla (*Diaphorina citri*). The infected trees are required to be removed for checking further spread of the disease. Control of insect vector through pesticides and use of certified disease-free planting material are measures to be adopted to keep the disease under control.

Powdery Mildew
- **Symptoms:** Powdery mildew (*Oidium tingtaninum*) is a common disease of citrus in India. Whitish powdery growth develops on young leaves (both sides) and twigs. The affected leaves get distorted in shape and reduced in size. In severe infection, leaf falling, premature fruit dropping and die back symptoms become apparent.
- **Control:** Dusting of sulpur powder (200–250 mesh) or spraying of wettable sulphur (1 kg in 200 litres of water) can control it.

Citrus Canker
- **Symptoms:** Citrus canker (*Xanthomonas citri*) is widespread and it is a very serious disease in acid lime. The disease is caused by a gram negative bacterium which affects leaves, twigs, fruits and thorns. The canker lesions appear as minute water-soaked roundish spots which enlarge slightly.
- **Control:** Pruning and burning of diseased twigs, especially before monsoon, protective spraying of 1% Bordeaux mixture to emerging flushes or application of streptomycin sulphate (500 ppm) are recommended to control it.

Extensive Package for Citrus Cultivation

Production technology for citrus suitable under Indian conditions has been developed through multidisciplinary research efforts. Some technology packages for Khasi mandarin oranges for north-eastern region and Nagpur mandarin for Maharashtra are cited.

Package of Practices for Mandarin Orange in NER (*source:* ICAR Research Complex for NEH Region, Barapani, Meghalaya, 2001)

The north-eastern region holds a prestigious place as an orange basin but the orchards largely remained neglected bringing down the yield and production. The ICAR Research Complex has launched a multidisciplinary project to investigate the causes and control of this serious malady. The following recommendations have been made to overcome citrus decline and maintain good production of orchards.

- ***Identification of productive mother trees:*** Mother trees producing more than 1,000 fruits/tree should be identified in different states. Seeds for raising seedlings may be collected from fruits of these trees.
- ***Bud-wood certification:*** The productive mother trees free from insect pests and diseases should be identified and indexed for greening disease.
- ***Standardization of rootstocks:*** The entire mandarin orange cultivation in north-eastern region is based on seedlings which make them susceptible to certain soil-borne diseases like *Phytophthora* sp. causing root rot and foot rot. It is advisable to grow budded plant on standard rootstocks like Rough lemon, Rangpur lime and *C. volkamariana.*
- ***Standardization of nutrient doses for declined trees:*** Application of N 300 g, P_2O_5 250 g and K_2O 300 g/tree has been found most effective in bringing declined mandarin trees to profitable bearing. Besides, application of micronutrients like boron, magnesium, zinc, copper, manganese and calcium as foliar spray twice a year is effective in correcting micronutrient deficiency.
- ***Nutrient doses for newly-established orchard:*** To raise healthy and productive trees of mandarin, it is essential to apply manures and fertilizers right from planting stage. A gradual increase in doses of manure and fertilizer every year has been found to be most profitable.
- ***Care of plants:*** To maintain the plants in healthy condition the following operations need regular attention.
- Remove water sprouts from the plants as well as from the rootstock (in case of budded plants) regularly.
- Train stems without branches up to 30 cm height from the ground level and allow the branches to develop afterwards only.
- Prune dead/diseased and unwanted shoots regularly.
- Avoid deep digging in basins.
- Mulch the basin with paddy straw during dry months to conserve the soil moisture and apply Bordeaux paste on the tree trunks.
- Apply manure and fertilizers as per schedule.
- Remove litchen and mosses regularly.
- Do not cultivate nutrient exhaustive intercrops after the plants have come into fruiting. Weeding and inter-culture operations should be done to keep the orchard floor clean throughout the year.

In heavy bearing, main branches may be supported with suitable stakes. After fruit harvesting, a general pruning of trees should be undertaken to remove all dead and diseased twigs.

Management of insect pests

Following schedule of pesticides is recommended for the management of different insect pests of citrus.

- First spray (March–April) Malathion 0.05% or Nuvacron 0.05%, Dimecron 0.05% for citrus psylla and endosulfan 0.01% for lemon butterfly.
- Second spray (June–July) Malathion or Dimecron or Nuvacron as above for mealy bugs, aphids, white fly and scale insects.

A regular surveillance for trunk-borer during July–August is essential. If there are new fros near the tree trunks/branches, clean the tunnel with an iron wire, insert a cotton swab soaked in Nuvan/Nuvacron/Petrol and plug the hole with mud or cowdung.

- Third Spray (September–October) repeat as per second spray for above insects. Apply Sevin 5% dust in tree basins and mix thoroughly in the soil. Remove webbing of bark eating caterpillars and treat the hole as recommended for trunk borer.

Management of diseases

Scab, powdery mildew, anthracnose/die back, gummosis and greasy spot are most frequently observed diseases of Khasi mandarin in the region. Following schedule is recommended for the management of various diseases.

DECEMBER – JANUARY

- Dead and diseased twigs, branches should be pruned off and burnt or buried deep under the soil.
- Application of Bordeaux paste on tree trunk up to 60 cm height from the ground level as well as on pruned cut ends.
- Scarification of weeping wounds (gummosis) along with dead portion and pasting of Bordeaux paint.
- Spray application of 1.0% Bordeaux mixture on trees.

MARCH – APRIL

Single spray of Bavistin (0.1%) + Nuvacron 0.1% coinciding with the new flushes to control scab, powdery mildew, leaf miner and aphids. After a fortnight, spray application of Bordeaux mixture (1.0%)/Blitox (0.25%)/ Captafol (0.2%) to control anthracnose, twig blight or leaf spots diseases.

MAY – JUNE – REPEAT OPERATION II

JULY – AUGUST – REPEAT OPERATION II

Calendar of Operations for Mandarin Orange Rejuvenation in NE Region

Month	Operations
December–January (after fruit harvesting in dry months)	• Pruning of dried branches • Removal of parasitic plants like Loranthus • Clean tree base, give shallow (5–10 cm) soil working of an area about one metre around the tree trunk • Paste tree trunk upto an height of one m with Bordeaux paste ($CuS0_4$–1 kg; lime–2 kg, 16–20 litres waters)
Mid-April to early-May (New leaf fully expanded)	• Apply 650 g of urea, 450 g super phosphate and 500 g of muriate of potash per plant in the tree base • Spray the tree canopy with a mixture of Zinc sulphate : 98 g Copper sulphate : 59 g Magnesium sulphate : 39 g Ferrous sulphate : 39 g Manganese sulphate : 39 g Lime : 180 g dissolved in 20 litres of water • In highly acidic soil with pH 4.5–5 apply 500 g of Dolomite lime per plant once in 3 years
April–May (disease and pest control) *Phytophthora* disease infected plants	• Rot or gummosis affected portion should be scrapped with a sharp knife taking care that no wood is damaged and paint with Bordeaux paste (1 : 2 : 3 lin seed oil) • Spray infected plants 2 times, first spray in April and second spray 40 days after with 1% Bordeaux spray. • Drench the soil at tree base with Ridomil MZ–72 (2.75 g dissolved in one litre of water)
Profilactic spray for disease and insects	• One spray of Bavistin (0.1%) and Nuvacron (0.1%)
November–December (trunk-and stem-borer control)	• Treating the soil, 6–9 cm deep around tree trunks (0.5 m) with 5% aldrin/sevin dust in dry month • A regular surveillance for trunk borer during July–August is essential. Whenever fross (excreta) are seen in tree trunk/branches, clean the tunnel (bored hole) with an iron wire, inject 3–5 ml carbondisulphide/petrol or insert a cotton swab soaked in Nuvan/ Nuvacron/Petrol and plug the hole with mud

Calendar of Operations for Production of Nagpur Orange (source: NRC for Citrus, Nagpur, Maharashtra, 2000)

JUNE–JULY

During June–July, due to monsoon rains, the stress is broken and the trees are full with new flush ready for *Mrig* (fruits maturing in February–March) bloom which may invite problems of insets, pests and diseases due to prevailing high humidity and warm temperature. Similarly, problem of water stagnation may also arise. Hence, remedial measures should be undertaken as per the need.

- After the first showers, apply Bordeaux paste to the trunk of citrus trees as a prophylactic measure against collar rot and gummosis caused by *Phytophthora* infection.
- Care should be taken to avoid water stagnation near trunk of the tree. In case of the problem of water stagnation dig 'V' shaped furrows in between the rows across the slope to drain out excess water from the orchard.
- Basins of irrigation should be leveled to avoid stagnation. The laterals of the drip system should be removed.
- In case of incidence of citrus psylla and leaf miner, spray Acephate or Dimethoate or Quinalphos at bud burst stage or when infestation is noticed on sprouts. Repeat the spray after 15 days.

AUGUST – SEPTEMBER

During this period, heavy rains cause water stagnation which result into suffocation of root system and also create conducive conditions for the *Phytophthora* diseases. The Nagpur mandarin fruits are in the process of maturity which with the colour break fall prey to the attack of fruit sucking moth.

- If an orchardist wants to go for new plantation, transplanting of plants be done.
- Stagnated water should be disposed by providing trenches along with the slope.
- According to age of the plant, apply recommended doses of N, P and K fertilizers.
- To reduce the fruit drop of *Ambia bahar* (fruit maturing in November–December) spray NAA or 2, 4-D with urea and bavistin which would reduce fruit drop by 10–20%.
- Fruit sucking moth punctures the *Ambia* fruits predisposing them to fungal infection resulting into fruit drop. Use light trap for its control. Destroy or burry the fallen fruits.

OCTOBER – NOVEMBER

During this period, *Hasta* flush is on the tree which again may be attacked by the insect-pests and diseases. Harvesting of *Ambia* fruits and fertilizer application are the operations to be undertaken during this period.

- Earthing-up of basins to break the crust formed that facilitates aeration for root zones.
- Basins for irrigation should be kept ready.
- Fruits should be guarded against the attack of fruit sucking moth.
- Remove and destroy fallen fruits.
- Harvesting of fruits should be taken up at right stage of maturity.

- Before harvesting the *Ambia* fruits, a systemic MBC fungicide spray should be undertaken thrice at 15 days interval.
- In order to ensure good crop in the next season, plants should be fertilized adequately so that proper supply of nutrients is constantly maintained.
- Apply Bordeaux paste after the cessation of monsoon.
- *Hasta* flush should be sprayed with insecticides against citrus psylla and leaf miner.
- During November, fruits of *Mrig bahar* may suffer from the attack of citrus rust mite. The mite feeding manifestation develops into 40–60% red brownish patch on the fruits after a month's period which is evident by end of December and January. It requires problem identification by an expert in November itself and if infestation confirmed, miticidal spray is essential.

DECEMBER – JANUARY

The *Ambia* fruits harvesting may get extended to December which leaves behind the dry shoots. Dry shoots harbour lot of pathogens and most of them multiply on it and later on they attack the plant parts. Hence, dry shoot removal should invariably be made, followed by fungicidal spray. The irrigation should be withdrawn in December to impose water stress for induction of *Ambia bahar*. During second fortnight of January the stress should be broken by irrigating the orchard thoroughly.

- Pruning of dry shoots should be taken up after harvesting of *Ambia* fruits.
- While pruning the dead wood, care must be taken to dip the blades of secateur in 1% sodium hypochloride solution after every plant to avoid the spread of disease.
- Immediately after pruning of dry shoots a systemic MBC fungicidal spray, e.g. Carbendazim should be given.
- Ensure that there is no excessive leaf fall. It could be an indication of disease infection. Undertake suitable control measures.
- Impose stress to plants. Duration of stress should be fixed depending upon the occurrence of low temperature, texture and depth of soil. If there are intermittent rains, fresh stress may again be initiated or irrigation may be continued depending on the time for which plants are exposed to stress.

FEBRUARY – MARCH

The *Ambia* flush is in full swing during this time which attracts insect pests like psylla, black fly, leaf miner and on the maturing *Mrig bahar* fruits and mite problem is quite serious. Regular irrigation should be given to maintain *Ambia* blossom.

- Irrigate the orchard at 7–10 days intervals.
- Apply farmyard manure (FYM) during January month to facilitate decomposition. Its mobilization starts after 3–4 months.

- If zinc deficiency symptoms are noticed, apply zinc sulphate to the plants mixed with sufficient quantity of FYM to be spread uniformly on the entire zone of feeder root concentration.
- Control mites on *Mrig* fruit with miticide and citrus psylla, thrips and aphids on young flush with systemic insecticides by spraying on new flush.
- If flowering is already there, do not undertake spraying because it will affect fruiting adversely due to the damage caused to stigma.

APRIL – MAY

Irrigation should be continued to maintain *Ambia* fruits. Fertilizers should also be given. There is a possibility of gummosis and other diseases. Digging, cleaning and maintenance work of the drainage channel be done during the month of May. The irrigation should be withdrawn in May for the *Mrig bahar* fruits.

- Frequency of irrigation should be increased from earlier usual schedule of 10–12 day to 4–5 days intervals.
- Apply fertilizer in April–May if there is flush during March, prior to which sufficient moisture in soil has to be ensured.
- Control of bark eating caterpillar should be done by injecting solution of Nuvan (0.1%) in the hole after clearing the infested trunk of the frass.
- As a prophylactic measure, spray Ridomil MZ–72 before the onset of monsoon or Alitte at 40 days interval on the plants effected with *Phytophthora* infection.

4

Management of Citrus Decline in India

CITRUS decline caused by various biotic and abiotic factors is a syndrome where citrus plants look unhealthy/sick after satisfactory performance for a few years. Sparse foliage, chlorotic leaves, twig drying and leaf fall, fall in productivity and die back of trees are noticeable symptoms encountered in declining citrus orchards. In India, causes of decline in different species and in different geographical regions vary considerably and the prevailing management practices largely determine the extent or degree of decline. In crop management area, nursery management, nutrient and water management, intercropping system, orchard hygiene and sanitation, and plant-protection measures are crucial in influencing the state of health of citrus plants. Citrus decline can be prevented and low to medium declined trees can be rejuvenated through adoption of integrated crop management practices.

RESEARCH ON CITRUS DECLINE IN INDIA

Around 1954, the ICAR, New Delhi, launched an elaborate research project on citrus die-back problem at Gonicoppal (Coorg orange) in Karnataka; Shrirampur (Sweet orange) in Maharashtra and at IARI, New Delhi (Plant Physiology Division). The major findings are:

- In high rainfall, hilly terrain at Gonicoppal (a) *Phytophthora* leaf fall and powdery mildew are major causes of decline. Adequate supply of NPK fertilizers and micronutrients and fungicidal sprays could check the decline; (b) Rangpur lime and Rough lemons were suitable rootstocks for mandarins.
- In heavy soils and under prevalence of Tristeza virus at Shrirampur in Maharastra, use of Rangpur lime rootstock showed better growth, disease resistance, and yield.
- The role of micronutrients in maintaining tree health was studied at the Division of Plant Physiology, IARI, New Delhi.

  Major recommendations of the research project are:
  - Supply adequate nutrition, including balanced application of micronutrients.
  - Use hardy rootstocks like Rangpur lime.
  - Control diseases timely.

The growers of Andhra Pradesh and Maharashtra started using budded plants on Rangpur lime, which is comparatively drought hardy and tolerant to certain diseases. Fertilizer use in citrus in Maharastra and Punjab was also on the increase.

In 1962, another research project on die-back was initiated at IARI, New Delhi, which showed that:

- Triseza, *Collectotrichum gloeosporioides, Diplodia natalensis, Curvularia tuberculata* and *Fusarium* sp. contributed to die-back condition.
- Association of citrus nematodes like *Tylenchulus semipenetrans* and some others were also linked with citrus decline.

In 1966, Dr L R Fraser, one Australian citrus virologist, reported that greening disease is primarily responsible for citrus decline in India. Later, citrus psylla (*Diaphorina citri*) was established as the vector for greening and it was claimed that spray of 0.2% Rogor insecticide effectively controlled the insect. Injection of Ledermycin or Tetracycline (500 ppm) suppresses greening symptoms temporarily. It is also reported that heat exposure of greening effected bud sticks at 45°C for six hours freed them from greening pathogens. The use of greening free nuclear seedlings and timely spraying of insecticides to control the insect vector may be simpler ways to keep the disease under check.

After studying citrus decline problem of Punjab, it was concluded that although Tristeza and greening were present, they may not be the major factors for decline.

Although Government of India launched a nation-wide citrus bud wood certification programme at four stations (Andhra Pradesh, Punjab, Maharashtra and Assam) not much headway could be made. Realizing the limitations of bud wood certification programme, a much broader project (All India Co-ordinated Citrus Improvement Project), covering all production technology aspects like standardization of rootstocks, manuring, irrigation, control of pests, diseases, etc. was launched by the ICAR, which has been continuing for developing complete package of practices for different agroclimatic region.

To deal with all aspects of research in citrus, ICAR established a separate National Research Centre for Citrus at Nagpur in Maharastra. The All India Coordinated Project (AICRP) operating at research centres in Andhra Pradesh (Tirupati), Assam (Tinsukia), Maharastra (Akola and Rahuri), Punjab (Ludhiana) and Tamil Nadu (Periakulam) addressed location-specific technology developmental programme as well as control of citrus decline.

Multilocational trials under AICRP resulted in identifying suitable rootstocks for mandarin and sweet oranges. Important useful recommendation on rootstocks are:

- Rangpur lime is a suitable rootstock for Nagpur and Coorg mandarins. Cleopatra mandarin and Trifoliate orange rootstocks are tolerant to Tristeza and *Phythophthora*. For Kinnow orange, both Rangpur lime and Cleopatra mandarins are good.
- In Vidharba region of central India, Nagpur mandarin on Rough lemon is the commercial crop. Flower regulation through water management is common. Rangpur lime is recommended as better rootstock. Virus cleaning through shoot-tip grafting (STG) has been

Glimpses of Citrus Decline in Different Regions in India

Nagpur mandarin decline in central region

'Mosambi' sweet orange decline in Marathwada

Khasi mandarin decline at Mamit, Mizoram

Khasi mandarin decline in · Jampui hills, Tripura

'Sathgui' sweet orange decline at Tirupati, Andhra Pradesh

Acid lime decline at Anantpur, Andhra Pradesh

Courtesy: A.K. Srivastava, NRC for Citrus, Nagpur successful and large scale production of healthy planting materials initiated at NRC for Citrus, Nagpur.

- In Acid lime a few HYVs have been released. Lime × Lemon hybrid tolerant to citrus canker developed at IIHR, Bangalore. Cross protection against CTV through milder strain of virus has been attempted in acid lime.

CITRUS DECLINE MANAGEMENT

Preventive measures

Proper site selection

- For semi-arid plains of Maharashtra, Andhra Pradesh and Tamil Nadu

Deep soil (>2 m deep) free from soil related constraints like hard pan, low organic carbon, salinity, poor drainage, high clay and $CaCO_3$ in subsoil should be preferred.

- For High rainfall NEH, Coorg and Kerala hills

Avoidance of steep (>30%) hill slope, highly eroded sites and adoption of contour planting, bench terracing, conservation technology are essential.

Use of disease-free planting material

Seedling raising in solarized soil, fumigated with Dozomet granules @ 50 g/m^3 is a desirable practice for elimination of *Phytophthora* pathogens.

Bud wood collection from indexed trees and virus cleaning through STG technique are essential. STG is a miniature grafting of scion shoot tip on toothpick size citrus rootstock *in vitro*. STG technique standardized by NRC for Citrus, Nagpur, to be adopted for bud wood certification programme and for establishment of disease free foundation blocks in major citrus production zones.

Proper rootstock selection – Rough lemon for vigour, Rangpur lime for drought hardiness, Cleopatra mandarin for high pH soil, Trifoliate and Troyer citrange for cooler hills – are recommended.

Orchard care

Integrated Nutrient and Water Management

Inadequate supply of major and micronutrients, erratic irrigation scheduling at 20 and 30% depletion levels cause citrus decline in mandarins and acid lime respectively. Irrigation improved tree growth and fruit yield in Nagpur region. In Barapani, Meghalaya, supplementary irrigation during December–March is essential.

Research results clearly established that:

- Drip reduces irrigation requirement by 40% compared to flood irrigation.
- Fertigation results in 30% reduction of fertilizer requirement.

- Microirrigation in microjet 180°(2/plant) and at 500 : 140 : 70 g of NPK/tree by drip is effective for Nagpur mandarin.
- Flood irrigation increases risk of spread of *Phytophthora* pathogens.

Plant Protection

Phytophthora diseases

Association of *Phytophthora nicotianae*, *P. palmivora* and *P. citrophthora* causing diseases in citrus is well established. Among *Phytophthora* spp. isolated from declined orchards, *P. palmivora* is highly virulent and most destructive. Ridomil MZ 72 @ 2.75 g/litre or Aliette @ 2.5 g/litre as spray and spray + drench controls root rot

Greening and Citrus Canker diseases

Greening is more on sweet orange compared to mandarins; Ledermycin (Tetracycline) at a concentration of 600 ppm along with Zn and Fe suppress greening.

Pruning of infected twigs, application of streptocycline and neem cake effectively controls citrus canker.

Integrated Pest Management

Biological control of citrus black fly through field release of predator *Mallada boninensis* @ 100 larvae/tree reduces black fly infestation significantly (42%) in Maharashtra.

Bark-eating caterpillar (*Inderbela* sp.) can be effectively controlled by administering 3–4 ml dichlorvos (0.1%) per-larval bore.

REJUVENATION OF DECLINED CITRUS ORCHARDS

Mandarin Orange

Step I: General care

- The plants where less than 50% twigs have only dried (low to medium decline) and trees where at least 50% of the trunk is still intact after attack of foot rot disease can be considered for rejuvenation. Only mono cultured citrus orchard are to be selected.
- After fruit harvesting and in December–January, prune dried branches, remove the parasitic plants like *Loranthus*, clean the base of plants and give shallow (5–10 cm) soil working at least in an area of one meter around the tree trunk. Paste the tree trunks up to an height of about one meter from the soil with Bordeaux paste (1 : 2 : 16–20 water).

Step II: Nutrition

Apply 650 g of urea, 450 g of TSP and 500 g of muriate of potash per plant in March–April or just before the onset of rains.

Till such time when micronutrient deficiencies of individual elements could not actually be determined through leaf analysis, a combined spray (cocktail) of following combination, once or twice during April-end or early-May when March flush leaves fully expanded is recommended: Zinc sulphate (98 g), copper sulphate (59 g), magnesium sulphate (39 g), ferrous sulphate (39 g) manganese sulphate (39 g), and lime (180 g) dissolved in 20 litres of water.

Also 500 g of lime should be applied once in 3 years in highly acidic soil.

Rejuvenation of declined Nagpur mandarin in Central India

Severely declined (80%) trees in Nagpur district were rejuvenated and 11–13 tonnes/ha fruit yield was recorded 2 years after treatments. Measures adopted are:

- Pruning of dead wood followed by Bavistin spray (1.0 g/litre water).
- Pre- and post-monsoon application of Bordeaux paste of tree trunks.
- Application of recommended doses of major and micronutrients.
- Irrigation at 4–7 days interval through double rings.
- Control of bark-eating caterpillar by administering 4 ml dichlorvos.
- Control of *Phytophthora* by Ridomil treatment (2.75 g/litre).

Rejuvenation of declined Khasi mandarin in NEH

Severely declined 15 years old abandoned orchards were rejuvenated in Meghalaya (Umbling, 300 m above MSL) and fruit yield of 10–12 tonnes/ha was recorded in the third year of treatments. Measures adopted are:

- Removal of vegetation other than citrus (tall forest tree species, bamboo bush, wild banana etc.).
- Parasitic plants Loranthus and Mikinia creepers cleared from citrus and dead twigs pruned.
- Tree bases leveled through soil working and half-moon terraces made.
- Bordeaux pasting up to one meter tree trunk.
- Borer holes plugged after injecting petrol.
- Soil application of NPK (400 : 250 : 400 g/tree) and foliar spray (Mg, Zn, B) in April–May.

Rejuvenation technology for Coorg mandarin

At Central Horticulture Experimental Station (CHES), Chettali Coorg mandarin trees at various stages of decline are being rejuvenated by adopting following practices:

- Pruning of dried branches/twigs
- Bordeaux pasting of tree trunks
- Application of recommended doses of fertilizers and micronutrients (Zn, Mg, Ca etc.)
- Application of 100–150 g of *Trichoderma harzianum* culture along with 5 kg neem cake to control *Phytophthora.*
- Pre- and post-monsoon spray of 1% Bordeaux mixture and spray of antibiotics/pesticides to new flushes.

Citrus decline management of Sweet orange in Andhra Pradesh

Primary causes for decline of sweet orange cultivar Sathgudi attributed to: (a) shallow and calcareous soil (b) greening, mosaic and root rot diseases and (c) water stress during summer months. Secondary factors include: malnutrition including micronutrient (Zn, Fe, Mg, Mn) deficiency. Rejuvenation technology as suggested by AICRP–Citrus, Tirupati Centre are:

- Application of recommended doses of chemical fertilizers and sufficient organic manures
- Pruning of dead woods and spray of Cu fungicides
- Bordeaux pasting of tree trunks
- Regular irrigation in dry months through double ring method
- Mulching of tree base during summer
- Application of *Trichoderma viride* @ 200 g/tree at the time of organic manuring
- Timely control of pests and diseases.

5

Post-Harvest Management in Citrus

POST-harvest losses in citrus takes place at various stages of fruit handling right from harvesting till the time fruits reach the consumers. Different pre-harvest factors and orchard management practices also influence post-harvest loss, including keeping qualities of fruits. The important pre- and post-harvest practices affecting post-harvest losses and marketability of produce are:

PRE- AND POST-HARVEST PRACTICES

Orchard Health and Pre-harvest Practices

Health and hygienic conditions of the orchard and tree nutrition are reported to affect fruit quality and storability of fruits. It is generally believed that increasing doses of nitrogen adversely affect keeping quality of fruits. Similarly, pre-harvest application of fungicides minimizes field infection and thus reduces decay losses in handling and storage. The pre-harvest sprays of Benlate (0.1%) or Baviston (1,000 ppm) at 15 days interval minimize post-harvest decay of fruits by more than 80%. Pre-harvest spray of TBZ (500 ppm) has also been reported to be effective in reducing post-harvest rot of Kinnow. Spraying of calcium nitrate (2%) two weeks before (in combination with 0.1% Baviston) helps in extending storability of Kinnow fruits considerably (up to 56 days under ambient condition and 98 days at 4 and 1°C).

Maturity Index and Fruit Development Periods

For Nagpur mandarin, yellow-orange colour break in fruit skin on nearly 75% fruit surface, minimum TSS of 10% and TSS/acid ratio not less than 14 should be the right stage of harvesting. Firm fruits (non-puffy types) harvested by clipping rather than snapping have better post-harvest shelf-life. Fruit diameter, length, weight and TSS increase up-to 280 days from fruit setting for *Ambia* crop maturing in November–December. For *Mrig* crop maturing in March–April, fruits usually take 240 days to mature from anthesis/fruit setting. Fruit acidity reduces during last phase of fruit development.

In Coorg mandarin, the best harvesting time for the main crop (December–February) is considered as optimum when fruit juice TSS: acid ratio is around 13–14, whereas for Darjeeling mandarin harvesting 214–215 days after fruit setting is considered to be desirable.

Kinnow fruits mature following single sigmoid growth curve. Although fruit size increase continues up to November, colour development through rapid increase in skin carotenoids takes place by November. January–February are considered to be proper periods of harvesting (TSS: acid 13.7 and 0.8% acidity). In Himachal Pradesh (Dhaula Kuan), TSS: acid ratio of 13–14, 13–14% TSS content and about 1% acidity are considered optimum for harvesting for Kinnow fruits.

In acid lime, for proper harvesting of summer crop (mid-January flowering) 160 days from anthesis, when fruit juice content is about 47.0% is ideal. In north Karnataka condition, 195 days and in south Karnataka, 165 days from fruit setting are suitable for harvesting of acid limes. In Andhra Pradesh, quality standards for acid limes have been suggested as 45–58% juice and 6.7–7.7% acidity. Proper stage of harvesting and maturity indices are, therefore, very important for determining marketability of fruits and minimizing post-harvest losses.

Methods of Harvesting

Conventional practice of fruit harvesting in Nagpur mandarin by snapping (twisting and pulling of fruits), collection of fruits in round baskets made of bamboo and heaping of harvested fruits at one place result damage to fruits and thus causes considerable post-harvest losses. Fruit harvesting by fruit clipper reaching to individual fruits in tree canopy by standing on ladders, collection of fruits in cloth bags tied around the waist of the picker are suggested as improved harvesting methods. Trials conducted at NRC for Citrus, Nagpur, showed that by following improved harvesting methods, 158 fruits could be harvested in one hour time and clipping fruit peduncle close to fruit helps in avoiding puncture injury to other fruits. For Kinnow orange also chipping with shears leaving 2 mm of fruit stock has been recommended (Ladaniya and Singh, 1999).

In South India, citrus fruits on a plant are normally harvested all at a time leading to mixing of good and poor quality fruits. In North India, Kinnow is harvested by conventional stick beating, garden secateurs and tailor scissors. Stick beating causes injuries to fruits, while garden secateurs leave longer peduncle (4–5 mm) attached with fruits, resulting puncturing damage to other fruits. In recent times, specialized Kinnow plucking scissors are in use. Attempts have also been made to use PVC tubes through which harvested fruits are rolled down to the ground.

Degreening

Degreening is sometimes done to improve fruit colour by removing green chlorophyll using Ethephon, an ethylene releasing compound, as post-harvest treatment. Degreening should be done only when it is a must as degreening normally shortens shelf-life of mandarins. Ladaniya and Singh (1999) reportd that by continuous flow method with 5–10 ppm ethylene gas, Nagpur mandarins with half to three-fourths green surface could be completely degreased within 48 hours at 26–28°C and 90–95% RH. In Kagzi lime, ethrel (500–2,000 ppm) treatment results in yellow colour development in 3–5 days at room temperature without adverse effect on fruit quality.

Degreening chamber of 170 cm length × 170 cm width × 227 cm height and a volume of 6,360 litres can hold nearly one tonne mandarins in plastic crates. The NRC for Citrus, Nagpur, has developed degreening unit using polyurethane foam insulated steel panels and fitted with humidifying, cooling and heating units having suitable control measures.

Mechanized Handling of Fruits

Packing line operations in citrus are common in most of the advanced citrus-growing countries. Mechanized sorting, washing and size grading has been standardized for Nagpur mandarins at NRC for Citrus, Nagpur. The packing line developed consists of 30 cm wide conveyers with washing and waxing by non-recovery sprays and grading by dimension sizer with 75–100% accuracy. The steps followed in the system are:

Sorting of fruits: Remove oblong, high collard, immature, puffy, blemished, deformed, deep green, bruished and diseased fruits.

Washing: Chlorine (1,000 ppm) can be used for disinfection before thoroughly rinsing in fresh water. All washer brushes should be sufficiently wet before using while in operation. Remove surface water before wax coating.

Waxing: Fruit surface is coated with stayfresh high shine wax (2.5%) containing Bavistin (4,000 ppm). The horse-hair brushes of waxer are saturated with water-wax emulsion solutions before use.

Drying: Wax coating is dried at 50–55°C in tunnel dryer.

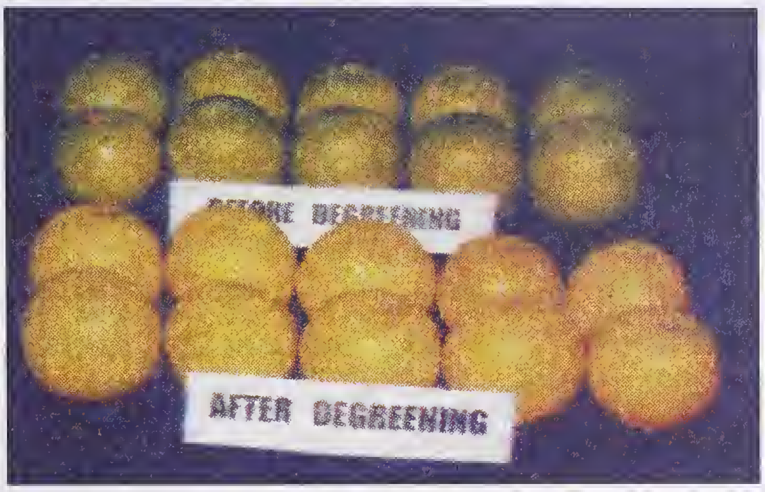
Sizing: Diameter of Nagpur mandarins vary from 5.5 to 9 cm. Size grading as small (5.5 to 6.1 cm), medium (6.11 to 6.7 cm), large (6.7–7.3 cm) and extra large (7.31–8 cm) is usually done through size grader.

Packaging

Ventilated containers of corrugated fibre board (CFB) with 16 kg/cm^2 bursting strength board is preferred for packing of Nagpur mandarins. Manual place-packing of accurately sized fruits is essential to immobilize fruits inside the box. About 5% of the area on two sides of box should be punched for proper ventilation. Use of perforated polyethylene bags (25–30 micrometer thick, 100–120 gauge with vents covering 0.4–0.5% bag area) are preferred for fruits handled during March–April. The polyethylene acts as moisture barriers, minimizing moisture loss when cold stored fruits are marketed under ambient condition. The NRC for Citrus, Nagpur, has developed a complete package for post-harvest handling of Nagpur mandarins from production to export shipment stage. For details, Extension Bull No. 3 and 21, of NRC Citrus, Nagpur, (1994) may be referred. Prompt forced-air precooling at 6–7°C after packing is essential before placing the fruit boxes for a long time cold storage. Mandarins can be stored well at 6–7°C with 90–95% RH for 45 days.

Mechanized packing line operations of sorting, washing, waxing and size grading have also been standardized for sweet orange cv. Mosambi.

Packing house operations for '*Mosambi*' sweet orange and Kinnow mandarins



Degreening of Mosambi sweet orange (colour change within 48 hours)

Removal of excess water

Surface cleaning (Washer)

Wax coating

Size grading (Rotary size grader)

Commercial packing house for Kinnow mandarins near Abchar (Punjab)

Reproducted from: Ladaniya, M.S. and Shyam Singh 1999.
Post-Harvest Technology and Processing of Citrus Fruits in India, NRC for Citrus, Nagpur.

For one tonne per hour capacity packing line, 30 cm wide conveyers can be used. Fruits washed with chlorine water (1,000 ppm), rinsed and waxed with stayfresh (451) coating (500–1,000 ppm TBZ) have a shelf-life of 90 days under refrigerated condition. In acid lime, fruits are mainly handled manually. The packing line developed for Nagpur mandarins by NRC for Citrus, Nagpur, can be used for acid limes with partial modifications in size graders and in treatments.

Vented plastic crates (55 cm × 35 cm × 30 cm) are being increasingly used as containers for bulk handling of Kinnow and mandarin oranges in fields and packing houses, replacing traditional bamboo containers. The mechanized fruit handlings for Nagpur mandarins and Kinnow in Maharashtra and Punjab have been reported. Amravati and Nagpur districts of Vidarbha region of Maharashtra have a few such units for handling of Nagpur orange, whereas in Punjab such facilities are established in Abohar and Bhatinda for Kinnow orange.

Control of Post-harvest Diseases

Post-harvest decay of mandarin oranges due to infection of various pathogens (*Botryodiplodia theobrommae, Colletotrichum gloeosporioides* and *Alternaria citri* as pre-harvest pathogens) can be controlled to a great extent, if proper disease control packages are adopted. The stem-end rot caused by *Botryodiplodia* sp. and *Alternaria citri* is commonly experienced.

- Three pre-harvest spraying (45, 30 and 15 days before harvesting) with Benzimidazole covering the whole canopy controls stem-end rot disease effectively.
- The post-harvest diseases caused by *Penicillium, Aspergillus* and

Table 14. Post-harvest treatments of citrus fruits for their better storability

Citrus spp.	Treatments	Storage temperature and RH	Storage period (days)	References
Mandarin orange				
Nagpur	Wax 2.5% + Carbendazim (2,000 ppm) + vented PE	20–35°C, 50–60% RH	21	Ladaniya and Sonkar 1997a
Khasi	Wax 3% + Benlate 350 ppm + PE	11–19°C	24	Karibasappa and Gupta 1988
Coorg	Wax 3% + 2, 4-D 100 ppm + PE	20–16°C	21	–
Darjeeling	2% Phenol	40°F	20	–
Kinnow	Wax 6% + Polyethylene	1–3°C 85–90% RH	90	Dutt *et al.* 1960
Kinnow	Wax 6% + diphenyl paper wrapping	19±8°C	90	Josan *et al.* 1983 Sinahrot *et al.* 1987c.
Sweet Orange				
Mosambi	Stayfresh 451 (1 : 1 dilution) + P.E	25±5°C	30	Ladaniya 1999c.
Mosambi	Wax 8% +2, 4-D 100 ppm + PE	Room Temperature	40	Dashora and Shafaat, 1988
Sathgudi	Wax 12% + vented poly bag	3.3°C	125	Sadasivam *et al.* 1972
Blood Red Malta	wax 12% + 2, 4–D (50 ppm)	Room Temperature	45	Bhullar 1982

Geotrichum spp. can be controlled by (a) washing fruits with chlorine water and (b) dipping them for 5 minutes in benzimidazole fungicides.

Various post-harvest treatments with and without wax coating have been tried by different workers and some of the promising treatments are shown in Table 14.

Pre-cooling and Cool Storage of Citrus Fruits

Citrus fruits can be stored well under cold storage conditions and Indian standards for storage of citrus fruits prescribed different treatments. Normally spoilage beyond 10–15% during long-term storage is not economical. Kinnow and sweet orange can be stored for a period of 3–4 months when if they are treated (Table 14). For Kinnow, pre-cooling at 5–6°C at 90–95% RH and air circulation ratio of 100 : 200 and cold storage at 5–6°C at 85–90% RH are prescribed for export. In cold storage, air circulation ratio between 30 and 50 is recommended.

For Nagpur mandarin grown in Maharashtra, chilling injury has been noticed at 3.5–5°C after 90 and 30 days in spring (*Ambia*) and monsoon (*Mrig*) blossom crops respectively. Darjeeling mandarin stored well at 4–6°C and chilling injury is noticed only at 1.5–3°C. Precooling of Nagpur mandarins through forced air cooling at 6–7°C at 90–95% RH is most suitable (Ladaniya, 1995). Hydrocooling by immersing fruits in cold water (6–7°C) with Carbendazim (500 ppm) is also effective and faster than forced air cooling. But elimination of surface water from hydrocooled fruits being cumbersome, forced air cooling is preferred.

A small-scale forced-air cooling unit to cool 500 kg packed fruits at a time has been developed at NRC for Citrus, Nagpur. For small growers, such cooling units with prefabricated insulated panels fitted with refrigeration unit (4,158 cal/hour capacity) and a blower (113.4 m^3/minute capacity) is suitable. The RH of 90–95% can be maintained by fixing an additional humidifier controlled by a humidistat. Fruits packed in 50 cm × 30 cm × 30 cm-sized CFB boxes with 4% vents on sides could be effectively cooled in such small units at 6–7°C and 90–95% RH.

Forced air precooling at 6–7°C with 90–95% RH is most suitable for Nagpur mandarins. Pre-cooler can be used with maximum efficiency by properly arranging packed CFB containers width and depth wise on two sides of fans.

Low-Cost Cold Storage (Zero Energy Cool Chamber)

In zero energy cool chamber, Nagpur mandarins, Kinnow and Darjeeling mandarins could be stored for 42, 60 and 42 days respectively under Delhi conditions during winters (Roy and Khurdia 1986). At Nagpur, Nagpur mandarins could be stored for 3 weeks at 25–26°C (maximum) and 10–12°C (minimum) and 90% RH (Ladaniya 1997b).

Long Distance Transportation

Nagpur mandarins from Maharastra are normally packed in wooden boxes of 45 cm × 35 cm × 35 cm size with rice straw for long distant transport. The conventional wooden boxes are not ventilated and therefore required aeration does not take place. In South India, citrus fruits (Sathgudi orange and acid lime) are also mainly transported loose in carts and lorries. In hilly areas (Darjeeling, Sikkim and NEH), fruits in small quantities are brought to assembly market as head-loads or on animal back. Ventilated CFB boxes of 46.5 cm × 27.5 cm × 27.5 cm size having 18 kg of mandarins are suitable for export of Coorg mandarins. For Nagpur mandarins, telescopic, 5 ply, CFB (50 cm × 30 cm × 30 cm) boxes are good and CFB boxes made from cotton stalks kraft paper are sturdy and economical. Acid lime fruits in Andhra Pradesh and Gujarat are usually packed in gunny bags with rice straw cushioning for long distant markets.

6

Citrus Processing and Value-Added Products

THE growth of citrus processing industry in India has been slow and is now picking up with increase in citrus fruit production. In developed countries, fresh orange consumption is declining on per caput basis, whereas processed orange consumption is increasing. North America and Europe collectively account for over 88% of the total world consumption. It is predicted that processed orange consumption will continue to expand in the emerging economies of Latin America, Asia and Eastern Europe. Orange-producing countries in Asia are expected to continue to expand production. China is projected to overtake Mexico as the third largest sweet orange-producing country and India will challenge Spain (*source:* Projections of World Production and Consumption of Citrus to 2010, Ref: http://www.fao.org/DOCREP/003/X6732_E/x 6732e 02.htm). China may become an important market for processed citrus. India is also importing some quantity of processed juice concentrate and marketing directly (Tropicana Brand) or after further processing (Real Brand). Globally sweet orange is major citrus type used in processing industry. Sao Paulo, Brazil and Florida, USA are largest processed orange-processing regions.

PROCESSED PRODUCTS FROM SWEET CITRUS FRUITS

Juice is the primary product in sweet orange and mandarin orange. Fruit juices are normally (FPO, 1955) categorized as: (a) fruit drinks and nectar, (b) sweetend juice and (c) unsweetened juice.

Normally for oranges, a fruit drink should have up to 40% of total fruit content, whereas for fruit juice, product should have more than 85% fruit content. Some bitter principles are present in citrus rind (in albedo) and seeds. At the time of juice extraction, care should be taken so that spots of bitterness are least disturbed when fruits macerated. The juice of sweet orange cv. Sathgudi in Andhra Pradesh is normally non-bitter, while Nagpur mandarin orange juice is more bitter. Sweet orange based juice processing industry is still weak in India. The mandarin orange fruits yielded approximately 40% juice in commercial manufacturing units. The CFTRI, Mysore, has developed medium-sized (0.75–1 tonne of orange/hour capacity) juice extractor, which gives clear non-bitter juice from orange. In more recent years higher capacity and more efficient machineries are being installed in commercial citrus-processing units.

Mandarin Orange Juice

Attempts have been made to commercially process mandarin oranges namely, Nagpur mandarin, Coorg mandarin, Khasi mandarin and Kinnow. From juice recovery point of view both Kinnow and Coorg mandarins are better than Nagpur orange (Table 15).

Table 15. Physico-chemical characters of important cultivars of Mandarin orange

Fruit Character	Nagpur		Coorg		Kinnow	Darjeeling	Khasi	Sikkim
	Ambia	*Mrig*	Main	Off				
Fruit weight (g)	125–150	100–150	100	96	150–175	75–95	100–125	90–100
Peel (%)	20–24	24–27	22–24	–	24–26	–	–	–
Juice (%)	42–43	41–42	49	54	48–52	40–54	42–48	39–40
Acidity (%)	0.6–0.7	0.5–0.6	0.8	1.1	0.9–1.0	0.6–1.3	0.74	0.4–0.5
TSS (°Brix)	9–10	10–12	11.5	10	11–12	10–11	10–14	10–11

Source: Ladaniya and Singh (1999) and others

Since fruits of Kinnow are heavier in weight, they contain more juice. The medium-sized fruits are better for juice recovery. The stored fruits yield 46–49% juice. The TSS also increases with storage, while acidity decreases. Thus, Kinnow can be utilized for juice processing for a longer period as storage both at ambient temperature and refrigerated conditions are possible for different periods (20–55 days). Since seeds in Kinnow are more, this factor needs to be kept in mind at the time of juice extraction. A few processing units in Punjab are engaged in processing of Kinnow successfully. Pakistan exports Kinnow juice economically. Coorg mandarin fruits, particularly main season fruits (December–March) are suitable for processing. Good quality fruits of main crop are also available for considerable period. The monsoon crop is, however, not preferred for production of processed juice. Coorg mandarins have been processed by a Growers Cooperative in Karnataka, where orange juice concentrates and other products are manufactured successfully.

In Vidharba region, Nagpur mandarins have been processed for manufacturing of citrus juice and other products. The data clearly show that mandarin orange juice was manufactured in sizable quantity by two factories located near Nagpur (Katol unit and NOGA unit) during 1997–99 period (Ladaniya and Singh 1999). The processing unit of 'Nagpur Orange Growers Association' (NOGA) produced as high as 13,000 gallons of single strength juice and another 2,000 gallons of bulk preserved mandarin juice concentrate in 1959 (Burke 1967). During 1995–96, India could also export small quality (about 13 tonnes) orange juice (frozen). Sweetend orange juice (canned) and juice concentrates are now being produced and marketed by Maharashtra Agro-industries Development Corporation (MAIDC), a Government of Maharashtra organization. MAIDC has taken over the NOGA unit near Nagpur and it was manufacturing other citrus products (Squash, Canned orange segments, Marmalade, Peel oil etc.) (Table 16).

In orange processed product trade, good progress, particularly in

Table 16. Mandarin orange products from major processing units in and around Nagpur

Products	1997–98 (tonnes)	1998–99 (tonnes)
Processed mandarins		
Katol plant	946.34	441.00
NOGA plant	172.00	7.00
Juice production		
Katol plant	394.00	189.00
NOGA plant	79.00	3.00
NOGA plant		
Orange squash	33.00	159.00
Orange marmalade	17.66	20.56
Orange canned juice	142.54	
Orange segments	42.00	–

Source: Ladaniya and Singh, 1999.

RTS sector, has been witnessed recently. In processed food sector commercial establishments like Parle Fruit Products, Godrej Foods, Kisan, Haldiram and others are marketing mandarin juice products in different brand names. For example, "FROOTI" and "JUMPIN", brands of RTS of mandarin juice in tetrapacks, manufactured by Parle Fruit Products and Godrej Foods, respectively are marketed in a large quantity throughout the country.

The RTS beverage having a minimum of 10% citrus juice, 10% TSS and 0.5% acidity is going to become a major drink, particularly during summers. Very good quality RTS can be prepared economically from citrus juice, from major mandarin orange cultivars grown in different parts of the country. Both Coorg mandarin and Kinnow have been successfully tried. The quality of Kinnow juice before and after thermal processing has been found to be suitable for preparation of RTS beverage. A comparative status of different quality parameters of fresh and processed Kinnow juice vis-à-vis RTS beverage as reported by Ranote *et al.* (1993) are shown in Table 17.

Table 17. Quality characteristics of fresh and processed Kinnow juice and RTS

Composition	Fresh juice	Processed juice	Processed RTS
TSS,°Brix	13.50	13.50	15.00
Total solids, %	14.50	14.75	14.89
pH	4.00	4.00	4.00
Acidity (citric acid,%)	0.71	0.72	0.45
Reducing sugars (%)	3.29	3.55	4.37
Total sugars (%)	6.48	7.60	9.95
Ascorbic acid (mg %)	22.40	20.20	3.00
Stormer viscosity (sec)	1.30	1.30	1.20
Tintometric colour units			
Yellow	49.80	39.80	6.50
Red	2.80	2.80	0.30

Source: Ranote *et al.*, 1993.

Sweet Orange Juice

Tight jacket sweet orange is better fitted for processed juice production. The Sathgudi orange of Andhra Pradesh, Mosambi of Maharashtra, and Malta of Punjab and Rajasthan are popularly known sweet orange cultivars in the country. Both Sathgudi of Andhra Pradesh and Jaffa variety grown in Punjab are preferred over Mosambi of Maharashtra. The quality of juice and recovery of juice per fruit are better in both of them. Certain other varieties, Blood Red Malta, Valencia Late, Hamlin and Pineapple tried in Punjab and Rajasthan, are also suitable for production of orange juice. The physico-chemical characteristics of important cultivars of sweet orange grown in the country are given in Table 18.

Table 18. Physico-chemical characteristics of commercially important sweet orange varieties grown in India

Characteristics	Sathgudi (Main season)	Mosambi	Jaffa	Blood Red	Pineapple	Valencia late
Fruit weight (g)	120–150	130–160	186	187	238	175
Peel (%)	–	–	23.9	27–30	27–30	27–30
Juice (%)	42–44	42–44	44	38	45–50	51–58
TSS (%)	10.74	9.8–10	8–9	10	9.5	10
Acidity (%)	0.58	0.35–0.45	0.6	0.6	0.58	0.70

Source: Ladaniya and Singh, 1999.

Since sweet orange fruits become unsuitable for processing after prolonged storage, Sathgudi variety with fairly long availability of about 6 months (September to February) is more suitable for large-scale processing units. The work conducted at CFTRI, Mysore, established that wax coated Sathgudi fruits stored for 4 weeks at room temperature and 12 weeks at 5–6°C can be used for making orange juice. Thus, combined with normal period of fruit availability and cold storage facility supply of good quality Sathgudi fruits can be ensured for 8–9 months in a year.

Sweet orange juice is very well-suited for marketing as pure natural product and canned or tetra packed products are in great demand. It is reported that canned juice of Blood Red Malta with good colour and non-bitter taste receives good consumers acceptance, while Malta orange of Punjab is suitable for RTS beverage (CFTRI, 1980). If extracted juice is stored under frozen condition, no bitterness is developed for a long period.

In recent years, asceptically packaged, sweet orange juice in polyethylene laminated tetra packs, are available in different brand names. Sweetened and non-sweetened juice under the brand name REAL, SAFAL, ONJUS, TROPICANA etc. are being marketed by different agencies. Some of these products are prepared mainly from imported orange juice. With large-scale area expansion under sweet orange in recent years, its juice availability from within the country is likely to increase. The Tropicana, a Fruit Juice Company, has taken some initiatives to evaluate the performance of Valencia group of varieties (Mid Knight Olinda, Hamlin, Early Gold and Ruby Nucellar) under Punjab condition, mainly for their use in processing sector.

Citrus Juice Concentrate

Citrus juice is normally concentrated in vacuum evaporators at low temperature to about 60°Brix and transferred to refrigerated closed tank in which it is blended with deaerated fresh juice to reduce to concentrate to 42°Brix. Advanced technologies of ultra filtration and reverse osmosis are also available for preparation of citrus juice concentrates. The fruits are cut into halves automatically and fed to citrus-juice extractor with lower cups and upper cups projectors. After oil recovery, juice is screened to remove seeds, sacs etc. The juice is then flash pasteurized to temperature of about 180–190°F. Both mandarins and sweet orange juices are concentrated in same evaporation principle under reduced pressure. The degree of concentration depends on quality of juice but usually it is 4 or 6 fold. The recovered oil is generally added to the concentrate before storage.

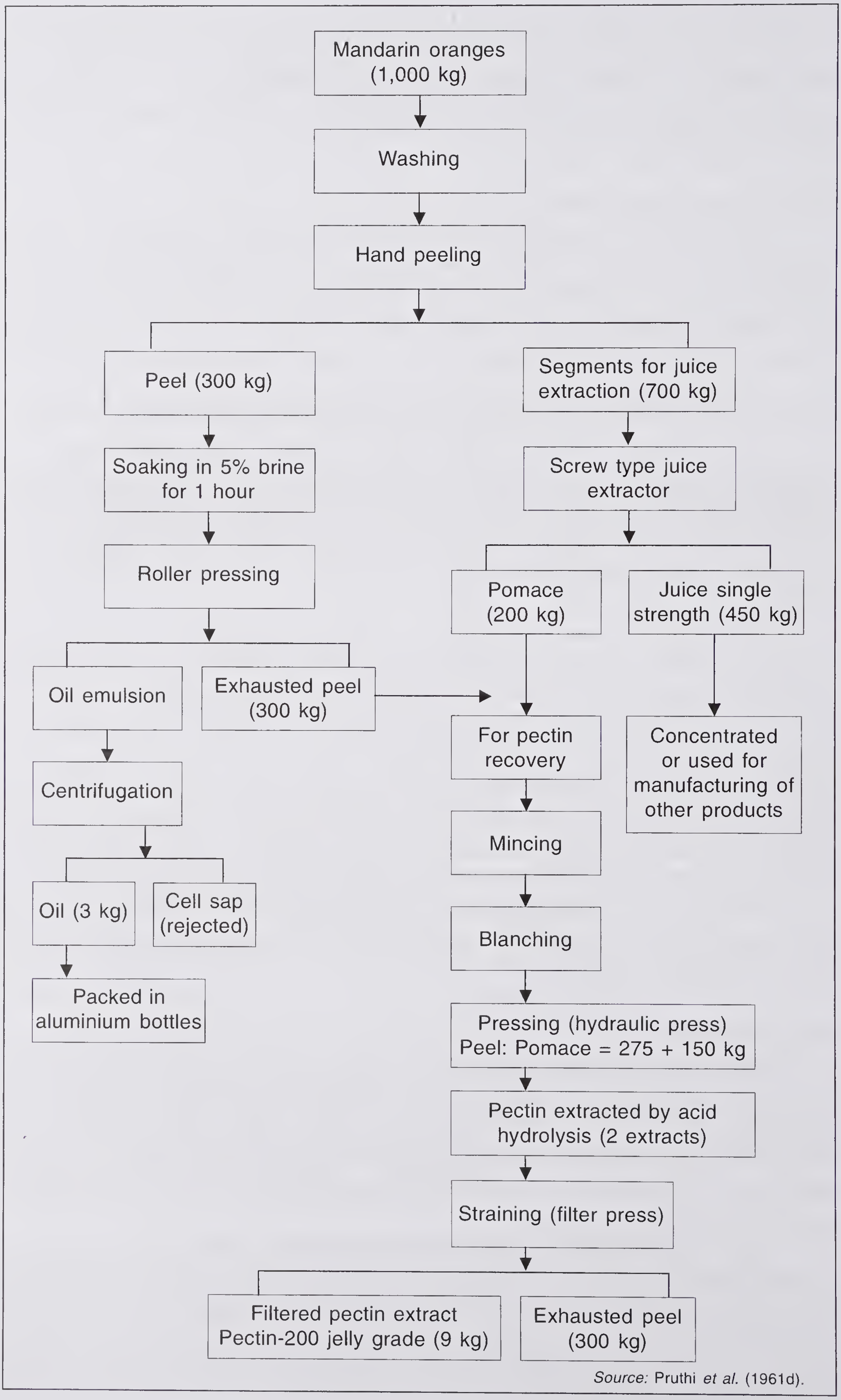
The juice concentrate of orange retains most of the nutrients and normal flavour is restored after addition of cold pressed peel oil. In Coorg mandarin orange juice concentrate addition of 0.66% of freshly extracted peel oil could restore the characteristic flavour. At NOGA processing unit, Nagpur mandarin juice concentrate could be preserved up to 9 months at 15°C when preserved with SO_2 (1,500 ppm) and packed in tin cans and HDPE containers. Kinnow mandarin juice could be concentrated to 40–42°Brix and in high Brix concentrates loss of quality (inversion of sugar and reduced ascorboric acid) was noticed (Sandhu and Bhatia, 1985).

Orange Juice concentrates are usually canned and stored. In tin cans and aluminium foil laminated pouches, juice concentrates can be stored up to 6 months at 0°C.

Orange Squash

Both from mandarin and sweet orange, squash can be prepared by adding sugar syrip to juice to get final Brix of 40–45°. Details of preparation of squash of different citrus types have been described by Girdharilal *et al.*, 1986. For bulk storage of orange squash other than glass containers, tin containers lined with paraffin and bee wax (3:1 mixture) are also found to be good.

Many other different types of processed products (frozen products, juice powder, comminuted beverage, canned mandarin segments, jam and marmalades, peel oil etc.) have been prepared from different citrus species and varieties. A schematic presentation for integrated process for mandarin orange made by Pruthi (1961d) for the process and possible products from mandarins shown Fig. 6.


Mandarin oranges (1,000 kg)
Washing
Hand peeling
Peel (300 kg)
Segments for juice extraction (700 kg)
Soaking in 5% brine for 1 hour
Screw type juice extractor
Roller pressing
Pomace (200 kg)
Juice single strength (450 kg)
Oil emulsion
Exhausted peel (300 kg)
For pectin recovery
Concentrated or used for manufacturing of other products
Centrifugation
Mincing
Oil (3 kg)
Cell sap (rejected)
Blanching
Packed in aluminium bottles
Pressing (hydraulic press) Peel: Pomace = 275 + 150 kg
Pectin extracted by acid hydrolysis (2 extracts)
Straining (filter press)
Filtered pectin extract Pectin-200 jelly grade (9 kg)
Exhausted peel (300 kg)

Source: Pruthi *et al.* (1961d).

Fig. 6 Mandarin Orange Processing

PROCESSED PRODUCTS OF LIMES AND LEMONS

India produces large quantity of acid limes but limited quantity of lemons. Some of the local lemons of North-Easterm region (Assam lemon, Napali oblong) and Hill lemon or Galgal, grown in the foothills of Western Himalayan region are not true lemons. Due to high extrable juice and thick rind fruits of Galgal (C. *pseudolimon* Tan.) are in good demand both for juice and pickle industry. In addition to various juice products from pulp, citrus peels are used for extraction of oil, fed to livestock and used in soap products. Lemon oil is cold-pressed from lemon peels and is used in baked goods, candy, furniture polish and insecticides. India is one of the top 10 countries in the world, producing 12% of the total world's production of lemons and limes (FAO 2000).

In lemons for processing use, juiciness and acidity of juice are main characters. The Galgal or Hill lemon having large fruit size is available in large quantity, particularly in foothills of Himachal Prodesh. Uttar Pradesh and Jammu region, is generally preferred by processing industry. Some other lemon types like Assam lemon in NE Region and 'Pant Lemon' are also grown to a large extent. Such varieties have not been exploited by processing industry so far at a large extent.

Acid limes are grown in many parts of the country, concentrating in Andhra Pradesh, Karnataka, Gujarat, Bihar, Maharashtra etc. Since under tropical climate of peninsular India, fruits are available almost throughout the year and production is in large quantity, acid lime possess great potential for processing. Lime juice and lime juice concentrates are important products. In addition, acid lime is largely used for pickle-making in households almost throughout the country. Some attempts have also been made for production of lime pectin and lime oil in Andhra Pradesh and Maharashtra. In addition to traditional acid lime cultivar 'Kagzi', some other improved varieties (Pramalini, Vikram, Sai Sarbati and Jaidevi) released recently are also good for processing industry.

The physico-chemical characters of some commercially important lemon and lime varieties compiled from different publications (Mookerjee *et al.* 1964, Chaliha *et al.* 1963, Desai *et al.* 1997) are in Table 19.

Table 19. Physico-chemical characters of fruit of lemon and limes

Fruit Character	Lemon			Acid limes		
	Galgal (Hill lemon)	Assam lemon	Eureka lemon	Kagzi	Sai-Sharbati	Jaidevi
Fruit weight (g)	425	120	70	40–50	50	45–52
Juice content (%)	40–41	33–34	27–28	45–48	55	50–52
TSS (%)	3.5–4.0	6.5–7.5	5.0	8–9	7.93	8–9
Acidity (%)	5.78*	6.0–6.4	3.5	7–8	7.29	7–8
Vitamin C (mg/100 g of juice)	49.5*	31.5–35.0	40	40–45	28.43	34–35

*Stored juice at '0' month (*Source:* Attri and Maini 1999).

Lemon Juice and Juice Concentrates

Lemon juice is the main product, which is extracted either through halving and burring machine (Dang, 1968) or by use of screw type juice extractors. The fruit juice is bottled or canned. Long storage of lemon juice results in discolouration, reduction of acidity and ascorboric acid contents. Deaeration and pasteurization is recommended and additions of preservatives (SO_2, KMS) are essential for storage of juice. Juice of Galgal fruits preserved with KMS (2,000 ppm) could be stored at room temperature for about a year without much deterioration in juice quality.

Flash pasteurization (195–200°F for 10–12 seconds) of clean lemon juice resulting up to 5-fold concentration is advocated for preparation of lemon juice concentrates. The frozen lemonade concentrates are used in large quantity. Lemon squash is another important commercial product, which can be stored up to 6–7 months.

Natural lemon juice in glass bottle without added flavour or colour is marketed by Dabur India Ltd. with the brand name 'Lemoneez', whereas Bagh Fruit, MAIDC (Nagpur) and others market lemon squash in commercial scale.

Lime Juice and Juice Concentrates

Acid lime fruits are comparatively smaller in size, than lemon fruits. Fully mature fruits with 9–10°Brix are considered better for processing. Juice extraction with screw pressing is avoided now a days and instead juice can be extracted by rotary juice press in which fruits are cut into halves and fed to drums with cups. Even by keeping the juice in wooden vats may allow settling down of pulp and some degree of clarification of lemon juice can be attained. Many a times such clarified juice is preserved in waxed wooden barrels after adding preservatives (700 ppm sulphur dioxides). In more recent times, ultra filtration and reverse osmosis process are being increasingly used by fruit juice industry. In contrast to conventional process, under ultra filtration process the loss in processing is minimum.

The lime juice concentrate, which is used as the base product for preparation of lime juice based carbonated drinks lemonade and others, is prepared by use thin film evaporator. The viscosity of juice increases with about 41°Brix at third stage of concentration and to 44°Brix at the final concentration. The concentration of lime juice at 30–40°C under vacuum to 65–45°Brix is reported to give better products. Carbonated lime drink with 0.2% acidity and 10°Brix, carbonated under 100 psi of CO_2 gas, has been found to be highly acceptable (Khurdia, 1989). M/S, Southera Citrus Products Ltd, Gudur, Andhra Pradesh is producing lime juice. A few other processing units in Jalgaon, Akola and Nagpur (NOGA unit) are also engaged in processing acid lime.

DEBITTERING OF CITRUS JUICE

Juice of sweet group of citrus, particularly of Nagpur mandarins, Kinnow and grapefruits become bitter soon after extraction. Juices of sweet orange cv. Sathgudi and Khasi mandarin or Coorg mandarins are less non-bitter in taste. The bitterness in mandarin is mainly due to the presence of bitter principle 'limonin', whereas in grapeful bitterness is largely linked with 'naringin'. Usually at the time of juice extraction when fruits are macerated the bitterness develops in juice. The bitterness varies with cultivar, fruit maturity, extractor type and even seasonal factors. For bitterness, threshold value of 8 ppm of limonin in orange juice has been reported.

In production of processed Kinnow juice, development of bitterness has been identified as a major constraint. In Kinnow, both limonin and naringin cause bitterness. Highest limonin content is found in Kinnow seeds (9.52 mg/g), followed by its peel (4.69 mg/g). The naringin on other hand, is more in peel (0.422 mg/g), followed by juice (0.230 mg/ml). Kinnow fruit juice develops full bitterness (0.218 mg/ml) in 4 hours at 25°C (Premi *et al.* 1994).

Debittering by passing the juice through ion exchange resin columns has been reported. The ion exchange resin absorbs considerable amount of limonins. Absorption of bitter principle in Amberlite XAD–16 resin has been found to be the best material for dibittering of Kinnow juice.

Attempts have also been made to debitter orange juice through enzyme actions. Some strains of mould producing limoninase and naringinase enzymes for degradation of bitter principles have been reported. *Aspergillus niger* 1,344 under optimized process has been found to hydrolyze bitter compounds of Kinnow juice effectively. A process for commercial production of debittering enzymes has been developed by Dhander and Shankhapal (1998).

The juice extraction process and type of extractor also influence the bitterness the citrus juice. Nagpur mandarin juice extracted by screw type extractor contains lower limonin, compared with juice extracted by halving and burring and hydraulic pressing. Bitter Nagpur mandarin juice blended with non-bitter juice of Clementine orange in a 1 : 1 ratio gave a product of acceptable bitterness (Ladaniya and Singh 1999).

QUALITY ASSURANCE OF PROCESSED PRODUCTS

The quality of processed citrus juice is influenced by various factors. Retention of natural taste and nutritive value depend much on processing methods, processing equipments, preservative used, containers in which juice is stored, storage temperature and others. Juice extraction process influence juice quality. Siddappa and Bhatia (1959) compared different juice extraction methods on juice yield and juice quality of mandarin orange. The lye treatment to fruit segments prior to juice extraction helps in avoiding bitterness of processed juice. Similarly, lye-treatment is effective in enhancing the keeping quality as well as in improving the organoleptic quality of Kinnow mandarins. The juice extracted by hydraulic pressing is non-bitter, whereas juice extracted by crushing with peel is highly bitter.

The type of packaging materials used and storage conditions also influence the quality of juice and RTS beverages. Metal cans of different sizes are used largely, in which mandarin juice heated up to 90°C is filled and then cans are sealed. In recent times use of flexible packaging material is on the rise. The thermal processing characteristics of flexible pouches have been studied and are now well understood for commercial use. Shelf-life of Kinnow-RTS beverage packed in flexible packs is comparable with that packed in rigid bottles and metallic containers when stored at 12–38°C for 24 weeks.

The fruit juice concentrates prepared through heating is most common. But in the heating process aromatic compounds are largely lost and generally the essential oils are added to restore the normal flavour of fresh products. The orange juice retains most of the nutrients when concentrated in forced-circulation evaporator. But here also the normal flavour is restored when cold pressed oil is added. Juice concentrated in industrial type plate evaporator is also possible. Coorg mandarin juice concentrates prepared/processed under plate evaporator and with addition of 0.06% freshly extracted cold-pressed orange peel oil maintained high quality standard retaining most of the nutrients and ascorbic acid contents of fresh juice (Radhakrishnaiah Setty *et al.* 1973). High-density polyethylene bottles are not suitable for packaging of mandarin juice concentrates since they develop some off flavours. Juice concentrates are usually canned in hot dipped and electronic (E 100) tinplate containers and stored under low temperature (below 30°C) conditions.

7

Marketing of Citrus Fruits

MARKETING of citrus fruits is still not very well-organized, and does not follow any uniform pattern throughout the country. Modern marketing infrastructures including packing house, storage and transport vehicles are largely absent in the major production belts. In India, broadly 3 general patterns are noticed in citrus marketing. They are:

- Entire crop is auctioned at fruit setting or at harvesting to individual contractors. Some changes in hands also take place from fruit contractors to others.
- The contractors or growers sell the crop to wholesalers or commission agents, who sell it to retailers or send to distant markets.
- Grower themselves make loose packs and sell to commission agents/ processing units. Lately, some big growers are involved in export also.

The growers' share in price paid the consumers greatly differs, depending on type of fruits (mandarin, acid lime etc), seasons and locality/ regions. In real sense, there is no regulatory system, standards and price control in citrus marketing. Under a market network study programme of the ICAR (2000–2002), some useful information as follows were generated.

MANDARIN ORANGE MARKETING

States covered under the survey were Maharashtra, North-Eastern states, (Meghalaya, Assam, Sikkim) and West Bengal (Darjeeling district). The marketing systems prevailing in different regions as identified during the survey are:

North-Eastern Region (NER)

Khasi mandarin, Sikkim orange and Darjeeling mandarins are traded mainly during December–February. The fruit maturity and harvesting time are delayed with increasing altitude. Bigger-sized fruits are generally harvested in early season from the warmer area in the plains/foothills, while smaller-sized but with better TSS: acid blended fruits are harvested from higher altitudes in late season.

Orange of Sikkim and Darjeeling district of West Bengal are marketed through the wholesale market in Siliguri. At Siliguri, wholesale market prices are fixed for a whole lot of fruits fixed under 'hand kerchief' in terms of 1,000 fruits. Once the price is fixed, the fruits are unloaded for sorting and grading. The purchaser bears the cost of unloading (Rs 3.50/1,000 fruits) and sorting (Rs 5/1,000 fruits). The trader normally pays Rs 1,000–1,200/1,000 fruits for domestic markets. For export to

Post-Harvest Handling of Mandarins in North-Eastern Region

Harvested Khasi Mandarin

Manual Grading of Fruits

Marketing of Khasi Mandarin in Meghalaya

Long Distance Transport of Mandarins in Nagaland

Bangladesh, Grade I fruits are packed in wooden boxes (24 × 22 inches) containing 300–350 fruits each. Each box weighs 40 kg. Truck is used for transportation with 200–250 boxes. The exporter has to pay Rs 12 for each wooden box and another Rs 26/exported box for other charges including customs cost. Road transportation takes place from a Indo-Bangladesh border point at Burimari, Haldibari in Jalpaiguri district of West Bengal. Importers purchase in Bangladesh currency Taka, convert into US Dollar and makes L.C. Fruits are sent from here to distant markets within Bangladesh.

In Sikkim, pre-harvest contractor usually pay Rs 40–50/100 fruits to farmers. The fruits are graded (size grading) as large, medium and small. Approximately 50% of the fruits harvested fall under Grade I category. Fruits are sent to Rangpo and Siliguri in open trucks, the bottom of the trucks often cushioned with paddy straw. The wholesalers usually pay 4–

5% of the total transactions to contractors. The growers sometimes bring the harvested fruits in bamboo baskets (DOKO) to local markets for retail sale. The predominant marketing channels in Sikkim are:

- Farmer → Pre-harvest Contractor →Wholesalers (Siliguri)/Wholesalers (distance market) → Retailers → Consumers. Harvesting injury (1% loss), insect damage (0.5% loss) and retail loss brushing and pressing of about 0.5% fruits at Gangtok market are reported to be the post-harvest losses in Sikkim orange. In contrast, Nagpur mandarins transported from Maharastra when retailed in Ganglok the post-harvest loss goes as high as 6–8%. Low temperature (10–15°C) in December–January is favourable for reducing rotting of fruits at market places.

In Assam (Kamrup, Tinsukia and North Cachar districts), pre-harvest contractors employed by the wholesalers purchase orchards at a price of about Rs 50/100 fruits. Part payment is made in advance, while the balance is paid at harvesting time. Guwahati is the main market where fruits are transported in open trucks, each carrying about 40,000 fruits are brought for auctioning. Commission agents and retailers are parties involved and prices are fixed under 'handkerchiefs'.

In Upper Assam (Dibrugarh–Tinsukia belt) many orchards are sold for a long period, even of 10–15 years and rate is negotiated after every two years. In Guwahati market, Nagpur mandarins are normally sold @ Rs 300–500/box of about 170–200 fruits at the wholesale market during March–April.

At Tamabil near 'Dawki' (Southern slope of Khasi hills of Meghalaya), border trade with Bangladesh takes place and fruits are transacted between the Indian exporters and Bangladeshi importers. The wholesalers normally pays Rs 50/100 fruits and Rs 6/100 fruits as harvesting charges. The retailer purchases the fruits by paying about Rs 140–145/100 fruits.

In Shillong, wholesale market fruits are brought by commission agents and sometimes by growers themselves. Bamboo baskets, each containing over 500 fruits, are used in transportation of fruits. The commission agents/contractors purchase fruits @ Rs 40/100 fruits, pays Rs 20/bamboo basket for transportation by bus and sold the fruits to retailer @ Rs 80–90/bhar (32 fruits). Consumers price in Shillong market varies from Rs 2.50 to 3.00/good-sized fruits. Farmers often bring fruits from nearby places and directly sell the fruits to retailer @ Rs 60–70/32 fruits.

Price realization by growers largely varies depending on market channels. In Guwahati market, wholesaler's-share is as high as 45% of consumers' rupee. In Gangtok market, producers share in consumers rupee is as high as 70%, when fruits are sold in a channel, Farmer → Retailer → Consumer, against only 29% in a channel like Farmer → Wholesaler → Retailer → Consumer. The study revealed that in N E Hills, growers are reluctant to sell their produce directly to market mainly due to small quantity of produce from small holdings, inaccessibility and inadequacy of transport facilities. The strong presence of market intermediaries like contractors often adversely influence the growers in taking interest in group marketing.

Maharashtra

- Nagpur is the main wholesale market for mandarins, where loose fruits from nearby areas are brought in trucks (8–10 tonnes/truck) or in tempo vans (1.5–2 tonnes/van). The fruits are generally auctioned either by unloading the whole unasorted lot or by arranging sorted fruits in circular heaps of 1,200 fruits each. The price of whole lot is fixed on per tonne basis. For long distant markets, fruits are packed in wooden boxes with 80–100 big fruits and about 25 kg gross weight per box of fruits. Based on size of fruits, fruit numbers per box varies greatly (80–200 fruits).

Mandarin orange marketing is better organized in Nagpur. Long distance markets in Delhi, Bihar, West Bengal, Karnataka and Tamil Nadu are well-linked and trading channels are well-established. The traders are to pay fixed rates for wooden boxes, sorting-grading of fruits, loading and unloading of fruits, transportation charges, market cess and commission to commission agents. In Nagpur, retailers pay @ Rs 7,300–9,000/tonne of fruit (during survey years) as purchase price. The consumers price at the same period varies from Rs 40/dozen (Grade I) to Rs 20/dozen (Grade III) of fruits.

ACID LIME MARKETING

Unlike mandarin orange, the practice of selling orchards to pre-harvest contractors is less prevalent in acid lime. Generally fruits are purchased by commission agents/wholesalers at market place. Fruits are directly sent by farmers to nearby wholesale markets. In Maharashtra, Nagpur, Akola and Ahmednagar are main markets, whereas is Andhn Prodesh, Hyderabad, Gudur (in Nellore district) are important ones. Fruits after harvesting are packed in jute/used cement bags and transported by tempo van, tractor trolley and even by bullock cart to markets. Unasorted fruits are auctioned in heaps. The commission agents/wholesalers/traders offer prices for whole lot of fruits, which are subsequently sorted/graded by traders. Traders normally pack fruits in bags of 40 and 80 kg capacities.

In Maharashtra, about 300–400 fruits are packed in 12–15 kg bags. The costs of packing is Rs 5–6/bag. Bigger-sized bags up to 25 kg are also used. The market channels in different places varies considerably. In Nagpur, main types of market channels reported are:

- Farmers → Commission Agent → Buyer (wholesaler) → Retailer → Consumer
- Farmer → Retailer → Consumer
- Farmer → Commission Agent → Retailer → Consumer
- Farmer → Commission Agent → Buyer from distant

Markets → Commission Agent in distant Market → Consumer.

Post-harvest losses of yellow fruits (8% loss) of acid limes are more than green fruits (1–2% loss) in wholesale market. At retail level loss goes as high as 20% or more.

Table 20. Demand-supply of different citrus types in Delhi markets

Mandarin orange (other than Kinnow)	In November–December and February to March, when large market arrival takes place. Sale price is highest in April for loose-skinned mandarins.
Kinnow mandarin	Arrivals start from December and continues up to February, with peak arrival in January. There is not much variation in the price of Kinnow during these months.
Sweet orange	Maximum arrivals of sweet orange (mainly Mosambi variety) takes place during August–September. Prices are lower during peak arrival time.
Limes and lemons	The arrivals of limes and lemons in Delhi market start increasing during March–April, with peak in May and continue upto July. Maximum surge in price recorded in April.

The Gudur market in Nellore district in Andhra Pradesh is largest wholesale market for acid lime in the country. Out of total acid lime production of about 6 lakh tonnes of fruts in Andhra Pradesh, Nellore district alone produces more than 3 lakh tonnes. In Gudur market, producers' share is 53% of consumers price when fruits are sold to commission agents directly. When fruits are sold to wholesaler of distant market (like Delhi), the marketing cost increases further as a result of which consumers have to pay more (Table 20).

8

Export of Citrus Fruits

THE export of citrus fruits from India is still insignificant. Mandarins are mostly exported to SAARC countries, while limes and lemons to Gulf countries. Some quantities of mandarin orange (Khasi mandarin from North East, Darjeeling mandarin, Kinnow mandarin, Nagpur mandarin) are exported to Bangladesh and Middle East countries (Saudi Arabia, UAE, Bahrain and Kuwait). Limited quantity of mandarins has also been sent to Sri Lanka, Singapore, Malaysia, Hong Kong, UK and the Netherlands. During 1993–94 to 2000–2001, more than four-fold increase in export of orange could be recorded, although in terms of quantity still the export volume is very negligible (26,822 tonnes of orange exported during 2000–01 against a total production of 13.9 lakh tonnes, which is less than 0.2%). Pakistan exports Kinnow to the tune of 41,171–51,000 tonnes (in 1997 export volume exceeded 89,000 tonnes), which is 8–18% of the total production.

The Nagpur mandarin, particularly harvested in March–April, enjoys a very unique position and with little market promotional activities export can be enhanced substantially. Air cargo tariff being high, export transportation by sea route in refrigerated containers is essentials for which both pre- and post-harvest production practices need to be standardized.

The details of APEDA-Agro exports statistics–2001 indicating the quantity and value of export of oranges and mandarins to different countries are shown in Table 21. During 2000–2001, out of 26,822 tonnes of fruits exported with a total value of Rs 273 million, Bangladesh alone imported 26,457 tonnes of fruits worth Rs 264 million. The mandarins from North-Eastern region are exported to Bangladesh and Nepal by trucks following traditional way of handling and packing without pre-harvest treatments or cooling.

The data also show that India lost its export markets to European countries like France, UK and Belgium, whereas it could enter Kuwait market in recent times. Quality of fruits being a watchword in export trade, mandarins from North Eastern region and Coorg region of Karnataka (which are some what different in taste compared to Nagpur mandarin), should also be promoted to export market. Uniform-sized fruits, free of scars, blemishes and bruises and harvested at right stage of maturity with good colour development should only be selected for export. The Manuals, Pre- and Post-harvest Practices for Production of Exportable Quality of Mandarins, including Kinnow, published by APEDA 2003, needs to be consulted and improved practices to be followed by the growers/traders.

Table 21. Export of fresh orange and mandarins from India

Countriy	1997–1998		2000–2001	
	Quantity (tonnes)	Value (million Rs)	Quantity (tonnes)	Value (million Rs)
Belgium	34.40	0.63	–	–
Bangladesh	17,793.00	130.40	26457.00	264.00
Bahrain	1.00	0.01	9.50	0.14
France	31.60	0.81	–	–
UK	41.60	0.64	–	–
Kuwait	–	–	18.00	0.28
Sri lanka	196.00	0.88	–	–
Mauritius	20.40	0.45	–	–
Netherlands	17.20	0.22	–	–
Nepal	7.85	0.07	13.00	0.10
Saudi Arabia	7.30	0.08	299.20	8.50
UAE	15.70	0.14	8.20	0.17
USA	11.00	0.23	15.80	0.73
Total	18,179.00	134.68	26,822.00	273.73

QUALITY STANDARDS

The quality standards for export of citrus fruits to European countries are prescribed and documented (FAO/WHO, 1997). The NRC for Citrus, Nagpur, has also published information on export of Nagpur mandarin (*Extension Bulletin No.* 21, NRC for Citrus, 1999). Some of the important quality export standards of citrus are:

Fruit size and Juiciness

- Minimum juice content in fruits: 42% in acid limes, 33% in mandarins and 35% in sweet orange.
- Minimum fruit size (diameter of equatorial section of fruits): 42 mm in acid limes, 45 mm in mandarin and 53 mm in sweet orange.
- Minimum quality criteria for Nagpur mandarin:
  TSS – not less than 10°Brix
  Acidity – 0.6–0.7%
  TSS: acid – 14 (not above 20)
  Juice content – 38–40%
  Skin colour – more than 2/3 of fruit surface yellow-orange colour
  Firmness – 3 kg/cm^2
- Quality specifications for Kinnow
  Fruit size – 60 mm
  TSS – 11–13°Brix
  TSS: acid – 12–14
  Skin colour – Golden yellow
  Firmness – 2.95–3.5 kg/cm^2
- **Packing of fruits**
  Full telescopic fibre board boxes which are strong enough to support

overhead weight should be preferred. In European countries, acid limes with net weight of 4.5 kg fruits/box, sweet orange 12–17 kg/box and mandarins 10–15 kg/box are usually imported. For export of Kinnow, normally 10 kg boxes (45 cm × 24 cm × 18 cm) in pallets of dimensions of 1,000 mm × 1,200 mm × 800 mm are used.

Pesticide Residue limits

Pesticide residue limits as specified by importing country shall be maintained and followed. In the absence of such limits, limits specified by Codex Alimentarius Commission shall be followed (Table 22).

The pre-harvest application schedule of pesticides is to be designed in such a way so that sufficient waiting periods are available before harvesting/exporting of the commodities. For example, for sweet orange cv. *Mosambi* waiting period of 32 days are required for monocrotophos residues to be within 0.2 mg/kg. Similarly, in acid lime waiting periods of 14–15 and 7–10 days are required for monocrotophos and phosphamidon respectively.

Table 22. Maximum permitted pesticides* residue levels for citrus fruits

Aldrin dieldrin	0.05
Bromide ion	30.00
Carbaryl	7.00
Deltamethrci	0.05
Dicofol	5.00
Dimethoate	2.00
Dithiocarbamates	10.00
Endosulfan	2.00
Ethon	5.00
Fenitrothion	2.00
Fenthion	2.00
Heptachlor	0.01
Malathion	4.00
Monocrotophos	0.20
Parathion	0.50
Phosphamidon	0.40
Thiabendazole	10.00
2, 4-D	2.00

*List mainly includes pesticides commonly used in citrus in India for which Indian standards are prescribed. Codex Standard covers many others with a total of 53 chemicals.

Pre-and Post-harvest Management for Export

For export to EC countries, pesticide residue analysis is mandatory and waiting periods of different pesticides are also prescribed. For EC Countries compulsory testing of following chemicals is required.

Mercury compounds: Mercuric oxide, mercurous chloride, other inorganic mercury compounds, alkyl mercury compounds, alkoxylakyl + aryl mercury compounds.

Persistent organo-chlorine compounds: ALdrin; chlordane, Dielrin, DDT, Endrin, HCH containing less than 99% of the gamma isomer, Heptachlor, Hexachloro benzene, Comphechlor.

Other compounds: • **Banned chemicals**

Ethylene oxide, nitrofen, 1, 2–dibromoethane, 1.2 dichlroethane, Dinseb, Binapacryl, Captafol.

- Chemicals of definite purity requirements
  - Docofol with more than 78% P. P. docofol and less than 1 g/kg DDT related compounds.
  - Maleic hydrazide with choline, potassium and sodium salts containing less than 1 mg/kg free hydrazide.

- Quintozene with less than 1 g/kg and less 10 g/kg pentachloro–benzene.

Coorg mandarin orange duely graded, waxed and packed in CFB boxes have been successfully exported to Singapore in refrigerated cargoship maintained at 4.4–5.6°C and 85–90% RH. Nagpur mandarin from Maharashtra and Kinnow from Punjab and Rajasthan have also been exported successfully to different countries (Sri Lanka, Gulf Countries) in refrigerated containers.

9

Research, Training and Credit Support for Citriculture

RESEARCH on citrus fruits received good attention and support from Government of India and ICAR, New Delhi. In 1954, ICAR launched a research project to deal with citrus die-back problem. Subsequently, through two All India Co-ordinated Research Projects (AICRPs), ICAR Institutions and SAU Centres conducted research on citrus.

R & D CENTRES

The research centres which made significant contributions in generating technology in citrus are: Indian Agricultural Research Institute (IARI), New Delhi; Indian Institute of Horticulture Research (IIHR), Banglore, with its research Centres at Gonicoppal and Chethali in Coorg; Punjab Agricultural University (PAU), Ludhiana; Andhra Pradesh Agricultural University, (APAU), Tirupati Centre; Mahatma Phule Krishi Viswavidyalaya (MPKV), Shrirampur Centre; Tamil Nadu Agricultural University, Periakulan Centre; and the ICAR Research Complex for NEH Region, Barapani, Meghalaya. Under the AICRP (Fruits) location-specific technologies covering all production and plant protection aspects of citriculture were developed. Similarly, under nation-wide bud wood certification programme of citrus carried in four states (Assam, Andhra Pradesh, Punjab and Maharashtra) some work could be initiated. Some of the technologies related to citrus decline have already been covered in earlier chapters.

Keeping in view of the importance of Nagpur mandarin, the IIHR, Bangalore established Central Citrus Research Station at Nagpur in July, 1985, which was upgraded to the status of National Research Centre for Citrus (NRCC) on 1 April 1986 to conduct mission-oriented research on all aspects of citriculture focusing Nagpur mandarin orange. Subsequently, acid lime and sweet orange were also added in the research programme of the NRCC. Some of the areas/issues in which NRCC, Nagpur, developed useful technologies are: (i) production of disease-free planting material and bud-wood certification system, (ii) leaf sample techniques and leaf nutrient standards, (iii) fertilizer schedules for Nagpur mandarin and acid limes, (iv) drip irrigation and fertigation systems for Nagpur mandarin and acid lime, (v) biological control of citrus black fly, (vi) chemical control of *Phytophthora* disease, (vii) mechanized packing line (1 tonne/hour capacity), (viii) maturity standard and degreening of Nagpur mandarin fruits, (ix) pre-cooling and short-term storage in evaporative cool chamber, and (x) decline management in Nagpur mandarin.

The NRCC has published 32 Extension Bulletins, 22 Extension Folders, 8 Technical Bulletins, 2 Manuals and 14 Books covering major issues of Indian citrus industry. Transferable production technologies for important citrus types are now available in different research centres in the country as for:

- Khasi mandarin at ICAR Research Complex for NEH Region, Barapani, Maghalaya.
- Nagpur orange and Acid lime at NRCC, Nagpur, Maharashtra.
- Kinnow orange at PAU, Ludhiana, Punjab.
- Coorg mandarin at IIHR, Bangalore.

Training Facility

There is no standard regular training course on citrus but need-based training on different aspects of citriculture for researchers, state department officials, field staffs and farmers have been organized by different ICAR Institutes/centres and SAUs. During 1989–2000, NRCC, Nagpur, successfully organized five training programmes and a 'Winter School' on citriculture. In recent years, after transfer of Trainers Training Centre (TTC) to the NRCC, Nagpur, it has organized another 10 batches of training for officials of North-Eastern Region (NER). The NRCC, Nagpur, has thus the capability to undertake training for different stakeholders engaged with citriculture. The 'Kisan Melạ' or 'Farmers Day' regularly organized by NRCC, Nagpur, allows large number of farmers from different parts of the country to visit the centre and get acquainted with the latest technologies in citriculture.

Credit Support for Citrus Production

Institutional funding supports for establishing new citrus orchards and rejuvenation of declined orchard are available under different central government schemes/projects. Under Horticulture Technology Mission (HTM) operational mainly in the hill states of the country, including NE Region (NER), funding support for area expansion and rejuvenation is available. It is reported that in the NER already additional area of 7,268 ha has been brought under citrus, out of which 4,732 ha is under mandarin orange alone. Rejuvenation of declined orchards through required fund provision has also been initiated in NE states. Similarly, under the National Horticulture Mission (NHM), citrus has been identified as a priority crop for development with adequate funding support.

The National Horticulture Board (NHB), Gurgaon, under its Commercial Horticulture Development scheme provide 20% back ended subsidy for new citrus plantations backed by advanced technologies. The NHB support is available only after bank loan and beneficiaries own share is ensured.

The National Bank for Agriculture and Rural Development (NABARD) under its farm sector investments has development unit costs and credit norms for all the three major citrus types, viz. mandarin orange, sweet orange and acid limes. The cost estimates include both the cost of establishment and maintenance of new orchards up to 5–6 years (NABARD, 2002). In citrus, depending the regional requirements bank loan to the extent of 85–90% of unit cost is available. With the introduction of Automatic Refinance Facility (ARE), the commercial banks have been given the liberty to finance various farm sector activities without prior approval of NABARD.

Citrus type	Unit cost/ acre (Rs)	Bank loan/ acre (Rs)
Mandarin orange	21,980	19,782
Sweet orange	27,330	24,597
Acid lime	26,640	23,976

The unit costs prescribed by NABARD for the year 2001–2002 (*source*: Unit Cost Farm Sector Investment in West Bengal, NABARD, Regional office, Kolkata. January 2002) applicable for West Bengal for different citrus types are shown (see box).

The bank loan was available upto first 5 years of planting and was restricted up to 90% of the unit cost. Based on technical feasibility and financial viability banks are allowed to modify suitably the estimates of NABARD.

The repayment period for mandarin orange and acid limes has been 8 years including 5 years of grace period. In sweet orange prescribed repayment period is 10 years, including 5 years of grace period. In a more recent model (*source:* www. nabard.org/roles/ms/ph/citrus.htm) bank loan of Rs 51,170/ha has been proposed for mandarin orange. The margin money as per NABARD norms for marginal farmers, small farmers and big farmers is 5, 10 and 15% respectively. In present model 15% of unit cost (Rs 9,030/ha) has been considered as margin money. For working out the financial viability and bankability of model project, the rate of interest is assumed at 12% per annum.

The details of cost estimates, yield estimates; sale price etc. as proposed in the model are reproduced below (Tables 23, 24 and 25):

As per the model scheme suggested the economic life of mandarin orchard will be 25 years and the bank loan with interest (assumed 12%/ annum) can be repaid within 10 years, including initial 5 years of grace period. The expected benefit : cost ratio worked out as 2.67 : 1.00, thus showing the profitability and economic viability of mandarin orange farming with bank credit support. Since under the Technical Parameters of the scheme 'Nagpur' has been shown as the variety it is presumed that

Table 23. Development of mandarin orange for 1 ha area

(Figures in Rs)

Particulars	Year							
	1	2	3	4	5	6	7	8 Onwards
Material								
Planting material (10% extra)	2,121							
FYM	825	1,238	1,650	2,063	2,475	2,888	3,300	4,125
Fertilizers	510	1,018	1,528	2,036	2,536	3,054	3,667	4,278
Plant protection chemicals and weedicides	400	400	575	575	775	775	900	900
Irrigation	700	700	700	700	700	700	700	700
Growth regulator and micronutrients	–	–	–	400	400	550	700	700
Workable fencing	2,000	–		–	–	–	–	–
Sub total-I	6,556	3,356	4,453	5,774	6,886	7,969	9,267	10,703
Labour								
Land preparation and layout	1,050							
Digging of pits	1,200							
Filling of pits and planting	1,500							
Application of fertilizers, pesticides, etc.	750	900	1,200	1,320	1,620	1,620	1,620	1,620
Interculture	900	720	720	600	600	600	600	600
Pruning/training	120	–	300	–	300	300	300	300
Irrigation	1,800	1,500	1,320	1,200	1,200	1,200	1,200	1,200
Harvesting and packing	–	–	–	–	300	360	420	480
Sub total (II)	7,320	3,120	3,540	3,120	4,020	4,080	4,140	4,200
Total (I + II)	13,876	6,476	7,993	8,894	10,906	12,047	13,407	14,903
Rounded off to	13,880	6,480	7,990	8,890	10,910	12,050	13,410	14,900

Unit cost, Rs 60,200 (capitalized up to the 6th year); Margin money (15%): Rs 9,030; Bank loan (85%): Rs 51,170

Table 24. Yield schedule and income from Mandarin orange

Year	1	2	3	4	5	6	7	8	9	10 Onwards
No. of fruits/plant	–	–	–	–	40	80	150	250	350	450
No.of fruits/ha	–	–	–	–	11,000	22,000	41,250	68,750	96,250	123,750
Gross Income (Rs/ha)	–	–	–	–	8,250	16,500	30,938	51,563	72,188	92,813
Expenses (Rs/ha)	13,880	6,480	7,990	8,890	10,910	12,050	13,410	14,900	14,900	14,900
Net income (Rs/ha)	–13,880	–6,480	–7,990	–8,890	–2,660	4,450	17,528	36,663	57,288	77,913

Table 25. Repayment schedule of Citrus Scheme

(Figures in Rs)

Year	Bank loan	Bank loan outstanding	Interest @12% p.a.	Deferred Interest	Income	Maintenance cost	Surplus	Repayment			Net surplus
								Interest	Principal	Total	
1	11,798	11,798	1,416	1,416	–	BL	–	–	–	–	–
2	5,508	17,306	2,077	3,493	–	BL	–	–	–	–	–
3	6,791	24,097	2,892	6,385	–	BL	–	–	–	–	–
4	7,557	31,654	3,798	10,183	–	BL	–	–	–	–	–
5	9,274	40,928	4,911	11,094	8,250	BL	8,250	4,000	–	4,000	4,000
6	10,242	51,170	6,140	13,234	16,500	BL	16,500	4,000	4,000	8,000	8,000
7		47,170	5,660	13,894	30,938	13,410	17,528	5,000	4,000	9,000	9,000
8		43,170	5,180	4,074	51,563	14,900	36,663	15,000	5,000	20,000	20,000
9		38,170	4,580	–	72,188	14,900	57,288	8,654	21,346	30,000	30,000
10		16,824	2,019	–	92,813	14,900	77,913	2,019	16,824	18,843	18,843
Total	51,170		38,673					38,673	51,170		

Repayment within 10 years with 5 years grace period.

financial analysis is applicable for Maharashtra state/central India. The planting material cost in that case will be much more (at least @ Rs 20/plant, budded on Rough lemon/Rangpur lime rootstock than shown (@ Rs 7/seedling) in the cost estimate. Since disease-free quality planting materials are essential for establishment of citrus orchards, it will be desirable to collect indexed vegetatively propagated planting material either from research establishments (viz. NRCC, Nagpur) or genuine and well-known nurseries only even by paying higher price.

Bank credit norms for citrus for different regions cannot be the same. For central India, particularly the Vidharba region of Maharashtra, cost of irrigation is considerable. Both for Nagpur orange and Kinnow mandarin drip/fertigation technology is available and needs to be transferred. Similarly, for NE Region, in the hill slopes soil conservation measures like bench/half-moon terracing and rain water harvesting are very essential for Khasi mandarin orcharding. While calculating the unit costs for development of citrus orchard all such location specific needs should be kept in mind for realistic credit support.

10

Future Outlook and Developmental Approach

IN first chapter, global production of citrus fruits vis-a-vis Indian scenario has been briefly discussed. For visualization of future Indian citrus industry, following assumptions are considered:

ASSUMPTIONS AND FUTURE OUTLOOK

- In India, use of citrus remained largely confined as table fruits and consumption of processed products, particularly the orange juice is still negligible. Demand of fresh fruit market is met mainly by the domestic production. The domestic market is likely to expand fast with increased purchasing power of middle income group Indians. Considering agroclimatic suitability, status of availability of technology and other support services, market elasticity and consumers preference, mandarin orange and acid lime will enjoy better position over sweet orange, lemons and grapefruits, the other 3 important players in global citrus trade.
- The total citrus consumption in the marketing year (MY) covering July 2004 to June 2005 for major citrus-producing countries was estimated at 62.4 million tonnes. Of which, fresh fruit consumption of 37.4 million tonnes (60%) and 25 million tonnes of processed consumption (Ref. http://www.fas.usda.gov/htp/Hort_circular/2005). Brazil and USA are largest processed orange-producing regions in the world and are likely to retain the position. Of the total citrus processing (basically orange juice), nearly 80% comes from sweet orange. Of the total quantity of world imports of different citrus types during 2003, sweet orange alone covered 47%. In global citrus trade, sweet orange is therefore, most dominant player, mainly for production of processed juice. Demand of processed citrus is increasing in major developed countries (USA, Canada, Europe and Japan) and even in Asian country like China, orange juice consumption has increased dramatically in recent years. Both for China and Japan, USA is major supplier and China may become an important market for processed citrus and fresh grapefruits. Indian share in export trade will remain marginal and that too for fresh mandarin and acid lime.
- The demand of processed citrus products is likely to increase in India in the near future. Import of orange juice in large quantity cannot be ruled out, unless sweet orange production with suitable processing varieties is increased drastically. The sweet orange cultivar 'Mosambi'

largely grown in Maharashtra is not a processing variety and earlier attempts to grow processing sweet orange varieties at commercial level in Punjab failed mainly due to decline problems. Presently, mandarin orange including Kinnow and acid lime grown in the country are utilized in a limited scale for production of different processed products.

- Although climatically, India suits well for lemon cultivation, commercial-scale cultivation of true lemons for processing sector did not take place. Among the worlds leading lemon growers and exporters, India does not figure anywhere and taking the examples of Guatemala or southern Mexico which have developed commercial lemon culture, mainly for lemon peel oil, in more recent times, India should also made serious attempts to promote lemons.

The technology for dehydrating the lemon fruits and preparing a powder for reconstituting in juice is available. Other than traditional lemon producing countries like Italy, Spain, Greece, and Turkey, even countries like Cyprus, Lebanon, South Africa and Australia have made lemon cultivation commercially successful. The excellent performances of some of imported true lemon varieties like Eureka in northern India and indigenous pseudo-lemon varieties like 'Galgal', 'Assam lemon' even under neglected condition show the promise of lemon, particularly for processed product (lemon juice, lemon peel oil, lemonade etc.) development. The increased consumption of processed citrus in India in coming years should be one of the primary considerations in area expansion programme. Grapefruit both as table fruit as well as for juice use does not seem to have much promise for Indian market.

POTENTIALS AND DEVELOPMENTAL APPROACH

Mandarin Orange

Although, India stands next to China in mandarin production, productivity level is quite low (8.3 tonnes/ha in 2001–02). The productivity of Kinnow mandarin is, however, reasonably high (14.8 tonnes/ha). The major growing (existing and potential) belts of mandarin are : (i) Maharashtra (Nagpur, Akola, Yavatmal, Buldana Amravati, Wardha) (ii) Rajasthan (Jhalawad, Kota) (iii) Karnataka (Chikmanglur, Kodagu, Hassan) (iv) Madhya Pradesh (Chindwara, Mandsaur, Betul, Ujjain, Shajapur, Rajgarh, Khandwa, Hoshangabad) (v) Assam (Tinsukia, Dibrugarh, Kamrup, NC Hills, Karbi Anglong) (vi) Nagaland (Mokokchung, Wokha, Zunheboto, Tuensong) (vii) Meghalaya (East and West Khasi Hills, Jaintia Hills, Garo Hills, Unium–RiBhoi) (viii) Tripura (South Tripura, Jampui Hills), (ix) Manipur (Tamenglong, Churachandpur, Thangel) (x) Arunachal Pradesh (Siang, upper Subansiri) (xi) Mizoram (Aizawl, Tuidam) (xii) Tamil Nadu (Dindigal, Salem, Nilgiries, Periyar) (xiii) West Bengal (Darjeeling) (xiv) Sikkim (East, West, South districts).

In addition to loose-skinned mandarins, Kinnow orange is also being grown in commercial scale in (i) Punjab (Ferozpur, Bhatinda, Muktsar, Hoshiarpur, Gurdaspur), (ii) Rajasthan (Sri Ganganagar, Hanumangarh) and (iii) Haryana (Sirsa).

Productivity-wise, for mandarin orange highest productivity (15.95 tonnes/ha) was recorded in Madhya Pradesh, followed by Assam (11.83 tonnes/ha), Nagaland (9.46 tonnes/ha) and West Bengal (9.49 tonnes/ha). In case of Kinnow, Rajasthan (22.19 tonnes/ha), and Punjab (15.0 tonnes/ha) are high productive states.

During the last decade, area expansion of mandarin orange has been most rapid in Maharashtra (from 62.2 thousand ha in 1991–92 to 124.2 thousand ha in 2001–02), followed by Madhya Pradesh (from 8.2 thousand ha in 91–92 to 11.7 thousand ha in 2001–02). In other states also, there has been marginal increase in area. Scope for further area expansion in Maharashtra is limited, whereas there is unlimited scope of area expansion in the North Eastern Region (NER), including Sikkim and Darjeeling hills of West Bengal. As per the available estimates about 40,330 ha area was under mandarins in the NER till 2001–02 and under the Horticulture Technology Mission (HTM) of Government of India, another 4,732 ha has been brought under mandarins in this region, thus totaling about 45 thousand ha. Varietal trials conducted in low altitude subtropical climate condition of Arunachal Pradesh showed excellent performance of Khasi mandarin, Nagpur orange and Sikkim orange with high quality fruits. Acidity development in fruit juice in Nagpur orange was recorded to be lower than all other varieties tested, while fruit yield in Khasi mandarin is much better. Keeping in view the potential and land suitability, there is a further scope of expansion of another 10,000 ha for mandarin orange in NER states (Table 26) as under:

Table 26. Area expansion scope in NER with mandarin orange

State	Location/districts	Area (ha)
Assam	Tinsukia, Jorhat, Dibrugarh, Kamrup, Karbi Anglong	2,000
Arunachal Pradesh	West Siang, East Siang, upper Subansiri	1,500
Meghalaya	Southera slope and Ri-bhoi, Burnihat, Umbling, Umian are of Khasi Hills; Garo Hills: Jaintia Hills	1,500
Manipur	Tamenlong, Churachandpur, Tipaimukh, Jiriban	1,000
Nagaland	Mokokchung, Wokha, Phek, Zunheboto	1,000
Sikkim	East Sikkim, West sikkim, South Sikkim (300–800 m)	1,000
Mizoram	Aizawl, Khawzawl, Tuidam	500
Tripura	South Tripira, Dhalai, Jampui Hills	1,000
West Bengal	Darjeeling (Kurseong, Kalinpong	500

Shifting cultivation or Jhuming is still prevalent in all the hill states, other than Sikkim. If part of the shifting cultivation area is demarcated for orange, further area expansion will be possible in the North Eastern Hills. In Chethali-Gonicoppal belt of Coorg in Karnataka, cultivation of Coorg mandarin orange should be revived back. Severe citrus decline and high competition from other plantation crops, coffee in particular, are the major causes for extinction of mandarin orange. Excellent quality of Coorg mandarin fruits and its potential for use in processing sector and export are well-known. Also, production technology including standardization of rootstocks for Coorg mandarin has been developed by IIHR, Bangalore, and its centres located in Coorg. In south, Coorg region of Karnataka and Niligiries, Periyar, Duidigul, Namakkal area of Tamil Nadu must be considered for further area expansion under mandarin.

Kinnow mandarin is restricted to Punjab, Haryana and Rajasthan. In the canal irrigated area, particularly in Sri Ganganagar of Rajasthan very high quality Kinnow with good yield is produced. The present (2000–01) area 15,903 ha must be expanded further as Kinnow is highly productive and economical. As Kinnow is successful mainly in Punjab, Haryana, Rajasthan, foothills of Himachal Pradesh and Uttaranchal, its expansion in newer area in Himachal Pradesh (3,000 ha), Uttaranchal (300 ha) and Uttar Pradesh (1,500) has been proposed.

The Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, has made an attempt to develop a 'Roadmap' for Indian Horticulture and accordingly a document has been prepared. Under the 'Roadmap' it is proposed to extend the area under mandarins by another 26,300 ha increasing its total production to 2,443,900 tonnes in next 10 years. In Kinnow, it is proposed to extend the area by another 7,500 ha and to raise the production to 428,500 tonnes from the present level of production 235,330 tonnes, mainly through increasing the productivity of existing area and new area expansion.

Perusal of data on yield of mandarins in different states of India show that inspite of vast increase in area, productivity of Nagpur mandarin in Maharashtra remained low (9.0 tonnes/ha), which is even lower than that of Assam (11.9 tonnes/ha), Nagaland (9.6 tonnes/ha) and West Bengal (9.5 tonnes/ha). In the entire NER, including Darjeeling hills of West Bengal, mandarin orchards are seedling (not budded) origin and no regular cultivation practices are followed. Nagpur mandarin, in Maharashtra, on the other hand, are mainly budded on vigorous rootstock Rough lemon or Rangpur lime and the management practices are followed in the orchards. Inducement of flowering by creating water stress and irrigation scheduling is common practice for Nagpur mandarin in Vidharba region. Shortage of good quality irrigation water and prevalence of *Phytophthora* root rot in heavy soils are two major constraints adversely affecting Nagpur orange production. It is very essential to address these problems and to improve the productivity of mandarin orange in Maharashtra. Integrated water and nutrient management and use of IPM practices for controlling insect pests and diseases are very essential. For area expansion, use of quality planting material free from diseases and budded on stress tolerant rootstock like Rangpur lime will be desirable. Useful production technology for Nagpur mandarin developed by the

NRC for Citrus, Nagpur, need to be transferred urgently through massive extension programme. For Kinnow, adoption of technology is much better in Punjab.

The ruling varieties of mandarin are Nagpur mandarin for Maharashtra and Madhya Pradesh; Khasi mandarin for NE region; Sikkim orange for Sikkim, Daerjeeling mandarin for West Bengal; Coorg mandarin for Karnataka; Kinnow for Punjab, Haryana and Rajasthan (Shri Ganganagar). The Clementine variety is gaining importance in Spain and other countries and needs field testing in India. Early ripening tangerine varieties (Daisy, Clemenules, Marisal) may be introduced.

Sweet Orange

Area- and production-wise sweet orange stands third in ranking after mandarin and limes and lemons. Rapid expansion in sweet orange area has been recorded during 1998–2002, concentrating mainly in Andhra Pradesh and Maharashtra. Future developmental approach of sweet orange, must be linked with the growth of processed orange juice industry and RTS sectors. The competitiveness of Indian sweet orange juice both interms of quality and pricing must be kept in mind before planning large area expansion with processed varieties. Other than Sathgudi orange of Andhra Pradesh, other prevailing varieties are not considered to fit well for orange juice processing. Although China has expanded its sweet orange area by many fold still it prefers to import orange juice in large quantity from USA to feed its fast expanding product market. Technological advances made in packaging, storage and transportation of fruit juice have made it possible to reach long distant markets with much ease and less cost. Further expansion of sweet orange should focus both for domestic fresh fruit and processed juice markets.

The major sweet orange-growing (existing and potential) zones are: (i) Maharashtra (Ahmednagar, Aurangabad, Jalgaon, Pune, Parbhani, Sangli, Kolhapur), (ii) Andhra Pradesh (Vijawada, Ananthapur, Nalgonda, Rangareddy, Prakasham, Nizamabad, Mahboobnagar), (iii) Punjab (Firozpur, Faridkot, Hoshiarpur, Bhatinda), (iv) Madhya Pradesh (Dhar, Badwani, Khargaon, Morena, Gwalior), (v) Rajasthan (Shri Ganganagar, Jhalawad, Kota) and (vi) Karnataka (Bijapore, Chikmanglore).

High rainfall and high humidity areas of north-east, Karnataka, Kerala and Tamil Nadu (where mandarins do well) are not ideally suitable for sweet orange. Eratic flowering and non-attractive coloured fruits are often experienced in such areas.

Productivity of sweet orange in Maharashtra (15 tonnes/ha) is almost double to that of Andhra Pradesh. The fruit yield of sweet orange both in Karnataka and Madhya Pradesh are comparable to that in Maharashtra, although area-wise both Karnataka and Madhya Pradesh are very minor states so far sweet orange is concerned. Sweet orange is more prone to certain deadly citrus diseases (e.g. Tristeza, greening) and should better be planted in semi-arid areas having irrigation facilities. Area expansion with sweet orange cv. Mosambi is almost five-fold in Maharashtra (7,000 ha in 1991–92 to 34.5 thousand ha 2001–02) during one decade. In contrast, reduction of sweet orange area in Punjab (from 13.1 thousand ha in 1991–92 to 3.1 thousand ha in 2001–02) has been very sharp. It is mainly due to 'citrus decline' phenomenon linked with diseases and certain other management problems. Area increase in Andhra Pradesh during the same period (1991–92 to 2001–02) has also been almost three-fold (32.3 thousand in 1991–92 and 85.1 thousand ha in 2001–02) and thus significant. 'Sathgudi' being the main variety, the additional production may help the processing industry with enhanced supply of raw materials.

At present (2001–02), sweet orange is cultivated in 126.4 thousand ha with a total production of 1210.4 thousand tonnes. As per the 'Road-map' of the Ministry of Agriculture it is proposed to enhance sweet orange production to 1,654.5 thousand tonnes, mainly through improved productivity of existing plantations and expansion in area in Andhra Pradesh, Maharashtra and Punjab. In Andhra Pradesh, the bud wood certification facility is available in Tirupati and only certified planting material should be used for area expansion programme.

Improvement of productivity in Andhra Pradesh through better management, particularly integrated water and nutrient management is very essential. Water stress during the summer months, greening, mosaic and root rot disease and unsuitable land with shallow and calcareous soil in certain areas are reported to be wide spread. By addressing such problems it should be possible to improve productivity of sweet orange in the state.

In Punjab, use of certified planting material (virus and greening free), use of *Phytophthora* tolerant rootstocks (Trifoliate orange, citranges), salt tolerant rootstock (Cleoptera mandarin), drip and fertigation practice for balance water and nutrient supply will be helpful in reviving back sweet orange cultivation in commercial scale. Punjab falls under subtropical climate and therefore, has potential to grow excellent quality sweet orange with high productivity. Areas with annual rainfall of about 700 mm or 500 mm with assured irrigation and a temperature range of 14°–40°C are well-suited for sweet orange. The exotic sweet orange varieties Jaffa, Hamlin and Pineapple performed well in terms of yield and fruit quality. In more recent years with the initiative of Tropicana Fruit Juice Company Valencias (Mid Knight Olinda, Hamlin, Early Gold and Ruby Nucellar) have been planted at different locations for evaluation. The Valencia orange can be grown successfully in even higher (800–1,300 mm) rainfall areas. Early season processing variety Hamlin, Ruby Nucellar and late season processing, varieties Olinda, Mid Knight, Hughes need to be tried for supply of fruits to processing units for prolonged period. Planting of local varieties Blood Red Malta on Karna Khatta rootstock should be avoided as there is compatibility problem in this combination.

Rajasthan, particularly Shri Ganganagar area, is another potential site for sweet orange. With assured irrigation and dry climate production of high quality sweet orange should be possible with good success. In such area, Blood Red Malta is already in production and Valencias need to be tried systematically.

The present varietal base with Sathgudi in Andhra Pradesh; Mosambi in Maharashtra and Madhya Pradesh and Blood Red Malta, Pineapple, Hamlin, Jaffa in Punjab, Rajasthan and Haryana is not unsound and fitted well for domestic fresh fruit markets. For processing sector, newer varieties need to be tried as indicated above.

Limes and Lemons

Acid limes and lemons are grown almost throughout the country, covering an estimated area of 161.3 thousand ha with a total production of 1,413.7 thousand tonnes (2001–02). Andhra Pradesh, Gujarat, Bihar, Karnataka and Maharashtra having more than 10 thousand ha each are growing acid limes on commercial scale and very rapid area expansion was reported from Gujarat (from 8.7 thousand ha in 1991–92 to 20.2 thousand ha in 2001–02) and Bihar (16.4 thousand ha in 2001–02) states. In Tamil Nadu also, considerable area (7.8 thousand ha) was under acid lime, but sharp fall in productivity (from 6.4 tonnes/ha in 1991–92 to 1.6 tonnes/ha in 2001–02) has been reported, apparently due to citrus decline problem. Andhra Pradesh with 40.7 thousand ha area and 488.1 thousand tonnes production is the number one state in the country. Productivity-wise, however, Karnataka (22.3 tonnes/ha), followed by Madhya Pradesh (16 tonnes/ha) are important states.

The so called lemons (Assam lemon, Hill Lemon, Galgal, Nepali oblong etc.) also occupy large area, concentrating in North-Eastern states (Assam, Tripura, Nagaland, Mizoram, Manipur) and in Northern States like Uttaranchal, foolhills of Himachal Pradesh and Punjab. Assam alone is reported to produce 54 thousand tonnes of 'Assam Lemon', followed by Tripura with another 40.3 thousand tonnes.

The Assam, lemon (lemon—citron type) is a seedless type, producing fruits almost throughout the year and without much care. It has spread in nearby Bangladesh also. In the acid group, lime predominates over lemon and there is large opportunities to expand the area in many other non-traditional areas both with limes and lemons. Quick decline caused by Tristeza virus and bacterial cankar are two major diseases in acid lime and the distribution pattern of acid lime shows that the crop faired well in comparatively drier areas of southern and central India. Large expansion of acid lime in eastern states like Bihar and Orissa and release of new improved varieties (Pramalini, Vikram, Sai Sarbati and Jai Devi) have opened up new opportunities in expansion of area and improvement in crop productivity. Acid lime being a highly polyembryonic species and nuceller seedling being initially virus free, propagation through seeds is a cheap and common practice in acid lime.

As per the estimates of NABARD, for establishment and maintenance of one acre acid lime orchard (up to fifth year) the unit cost is approximately Rs 26,640, which is affordable and for which bank loan of 90% of unit cost is also available. Acid lime expansion in drier part of Uttar Pradesh (Aligarh, Etah, Manipuri, Mathura and Agra) should be possible. Similarly, in semi-arid parts of Karnataka and Maharashtra crop can be expanded further with assured irrigation support. In the 'Roadmap' of Ministry of Agriculture it is proposed to enhance the production of limes and lemons to 1,838,100 tonnes in the next 10 years by increasing the productivity and extension of area.

Development of lemons needs special attention and thrusts. Unlike acid limes, lemons are weakly polyembryonic to monoembryonic and vegetative propagation (rootage, graftage) is common in lemon. Multiplication of quality planting material of true lemons, therefore, would need attention and care. Other than Eureka lemon and a few selections released by GBPUAT, Pantnagar (Pant Lemon) mother wood source of planting materials of true lemons in the country is limited. Also, lemon varieties differ considerably for their end use. For example, 'Villafranca' is considered as a good processing variety, while 'Eureka' lemon is used more as table fruit (slices served as a garnish on fish or meat or with hot tea).

There is a need to introduce true lemon varieties namely, Eureka (including clonal selection Allen, Cook, Lambert Eureka), Lisbon, Villafranca, Ponderosa and others and try them in cooler northern India. Lemons are now grown commercially in wide range of climatic conditions of Guatemala, Southern Mexico, Southern Africa, Australia, medium-high elevations of Philippines, in addition to traditional Italy, Spain, Greece, Turkey and others. Lemons are also adapted on drier climates such as Egypt and Iran. World lemon and lime production is projected at 10.6 million tonnes in 2010, an increase of 15% from 1996–98 level. Lemon and lime consumption is found in many countries of the world and imports are increasing rapidly. Strength of India has not been fully realized in promoting lemons so far and it needs priority developmental attention to establish rightful place of lemon, both in processing sector and in the export market.

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